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ABSTRACT

Presented in this publication are summaries of projects in advisory services, coastal zone studies, fisheries and aquaculture, marine products, and ocean engineering. A listing of publications and an activity budget are included. The Annual Report for 1973-1974 is intended to be a general overview of the total activities of the Sea Grant Program which supported projects that involved the services of 271 people, including graduate and undergraduate students from seven University of California campuses, a state university, a major state university laboratory and at a private university. (Author/EB)

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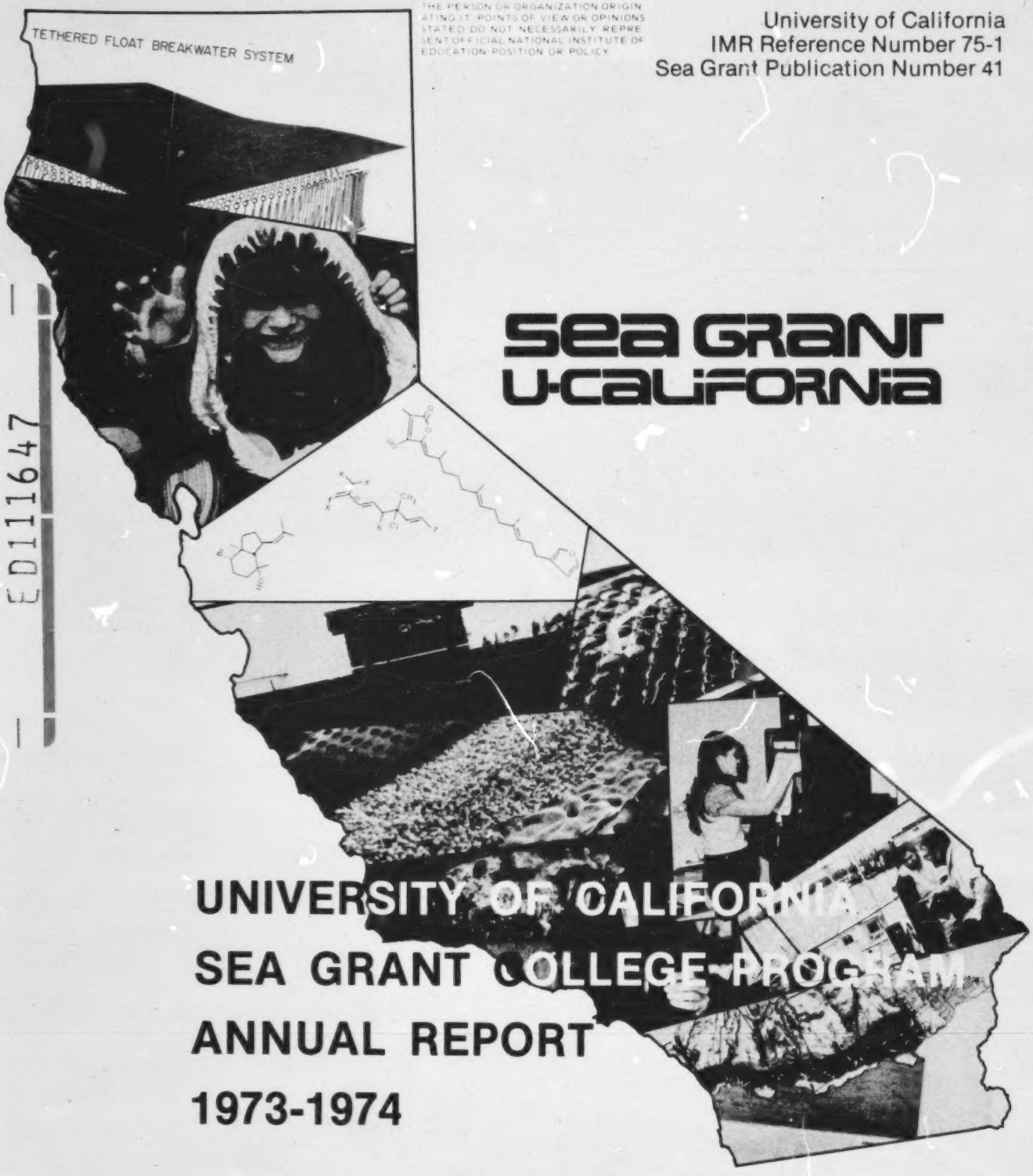

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UNIVERSITY OF CALIFORNIA SEA GRANT COLLEGE PROGRAM

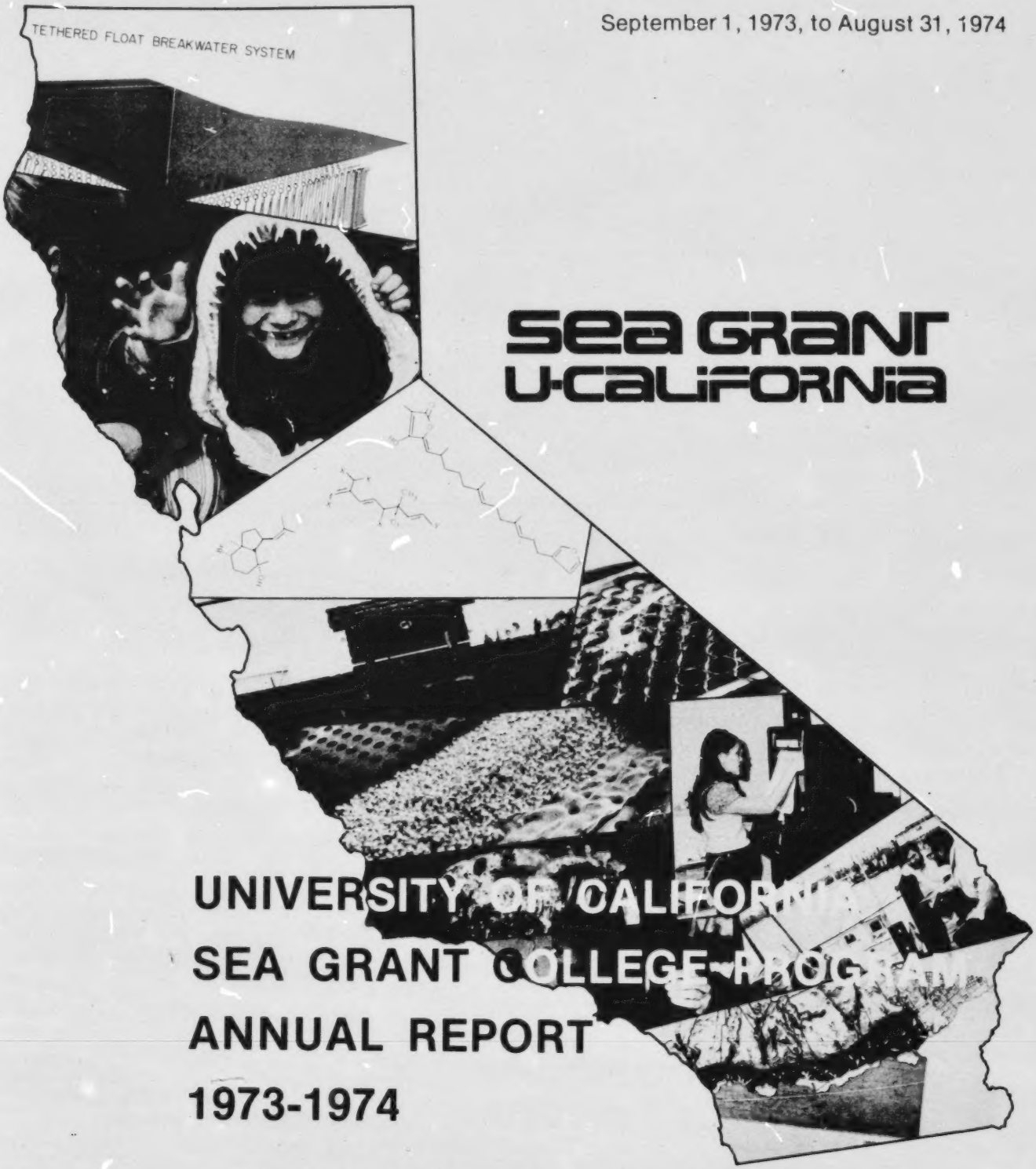
ANNUAL REPORT 1973-1974

A report on the University of California Sea Grant College Program for September 1, 1973, to August 31, 1974.

SE 019 492

What UC Sea Grant is all about—the program is described for the 1974 site team by (left to right) Maynard Cummings, Advisory Services Coordinator, Robert Twiss, Coastal Zone Studies Coordinator and J. D. Frautschy (extreme right), Program Manager, as Thomas W. Thompson, Fisheries Coordinator, and Herbert W. Frey, California Dept. of Fish and Game (left to right in second picture from right) wait their turn to speak.

September 1, 1973, to August 31, 1974



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UNIVERSITY OF CALIFORNIA
SEA GRANT COLLEGE PROGRAM
ANNUAL REPORT
1973-1974

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INTRODUCTION

Senate Bill 755 introduced by State Senator John Stull of San Diego, was passed by the legislature and signed into law by Governor Ronald Reagan on October 3, 1973. This statute provides state funds in the amount of $500,000 annually for a period of five years to be used as matching funds for Sea Grant projects of California institutions of higher education that have clearly defined benefit to the people of the State of California.

While this added financial support of the Sea Grant Program is useful, particularly in a year of tight budgets, even more important is the recognition and acknowledgement by the State of California that the program benefits the public. This, of course, is the state-federal partnership that should aid us and the Office of Sea Grant in demonstrating the value of increased federal support of California Sea Grant.

Beyond these implications of this law, its implementation provides a welcome opportunity for additional regular and mutually beneficial communication between government and the academic community.

Plans are progressing to enable our Marine Advisory Service to provide more adequate geographic coverage of California's coastal counties by increasing the number of field advisors and specialists and to provide a broader spectrum of services, information, and publications. This planning activity is being carried on in coordination with representativesd of the University of Southern California and Humboldt State University, organizations also involved in providing Sea Grant marine advisory services in California.

Although our research efforts focus on wise utilization of marine resources, projects cover a great diversity of related subjects. There are social and legal studies related to coastal zone management, investigation of the aquaculture of various plants and animals, experimentation with new compounds derived from marine organisms, improvement of the marketability of canned tuna by improving canning processes, and development of a novel wave-protection system, to describe a few.

The policy of the University of California Sea Grant Program is to seek out the most qualified research talent and the best applied research projects wherever they may exist within the state's institutions of higher education. This year there were Sea Grant projects at seven University of California campuses, a State University, a major State University laboratory and at a private university. The program supported projects that involved the services of 271 people, including 62 graduate students and 11 undergraduate students.

The formerly separate program of Moss Landing Marine Laboratories (a consortium of six California State University campuses) has contributed several projects in research, education, and advisory services and has now become an important element of the total University of California Sea Grant College Program.

This annual report is intended to be a general overview of our total activities. More detailed information about any aspect of the program will be on request.

J. D. Frautschy
Program Manager

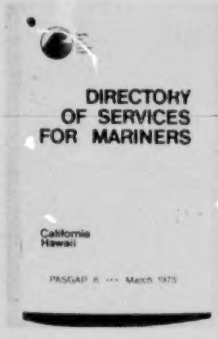
Half-pound saltwater-reared salmon are released into San Francisco Bay to improve fishing.

ADVISORY SERVICES

The Sea Grant Marine Advisory Program, part of the UC Cooperative Extension system, expanded its staff with the addition of a statewide seafood technology specialist and a local marine advisory on the North coast. The advisory staff not only seeks and transmits information from a variety of sources to the marine community, but also feeds back problems and opportunities for further research.

The energy "crisis" lessened the number of students visiting the SIO aquarium. The project staff responded by continuing the education at the local schools and hospitals with displays and programs. To ensure public awareness about the issues involved in the Law of the Sea Conference, a special edition of the USD law review was devoted to the topic.

Local volunteers loaded and systematically placed these tire modules off the Ventura County Coast to enhance local fisheries.



Directory of Services for Mariners, useful guide for California fishermen and boaters, was compiled by the Sea Grant Marine Advisory Program, in cooperation with PASGAP (Pacific Sea Grant Advisory Program.)

Marine Advisory Programs

Maynard W. Cummings

The Marine Advisory Programs took a variety of routes to dispense information and translate research results—coordinating a project to introduce salmon for sportsmen into San Francisco Bay, publishing seafood facts for consumers; holding workshops with tax insurance, and health tips for fishermen, giving expert councel to processors; and helping design a statewide plan to coordinate Sea Grant advisory services.

University-wide Marine Advisory Program unification became a reality this year and the increase in effective delivery of services was evident. The Marine Advisory Program Coordinator position became a full-time assignment. The Moss Landing Marine Laboratories' participation in the Program was made possible by reactivation of funding for that facility as a component of the UC Sea Grant College.

The active participation of UC Cooperative Extension staff in advisory services and the Marine Advisory Program personnel expansion were significant forces within Marine Advisory Programs contributing to its acceleration. The maturity of overall program guidance within the Sea Grant College and inclusion of Advisory Services at the planning and directional levels was an important influence for program solidarity.

Marine Advisory Program staffing strength and an awareness of the needs of the commercial fishing industry and related handling, processing and marketing businesses brought major attention to focus on this large and important social and economic segment of California. The assignment of a local advisory agent to the block of counties north of San Francisco Bay fostered a surge of activity in that area.

Support to Area Advisor

The Marine Resources and Seafood Technology Specialists, County Cooperative Extension staff, and federal and state agency personnel supported the Area Advisor in exploratory fishing for spot prawn and investigation into handling and marketing methods for this species.

Similar preliminary investigations were begun for the tanner crab.

Trap fishing for rockfish was discussed with fishermen interested in this approach.

Fishermen were made aware of the possibility of using the Scottish seine as a means of selectively taking kingfish for the San Francisco Chinatown market or other little-utilized species in the nearshore area.

A by-products company and fish processing plant were encouraged to try to develop an economically sound system for conversion of fish wastes to poultry feed.

Training workshops for fishermen dealt with business management, tax computation and recordkeeping, capital, construction, fishing vessel hull insurance, marine hospital services, net mending and gear development, use of Atlantic Western and other trawls, and general informational subjects such as progress in research and management of crab and other major species.

Silver salmon in the Bay

A major advisory program effort was coordination of an experimental silver salmon introduction into San Francisco Bay. The National Marine Fisheries Service Tiburon Laboratory, California Department of Fish and Game, and the Tyee Club of San Francisco brought 8,000 juvenile coho salmon from the State's Mad River Hatchery at Arcata to floating pens at Tiburon in San Francisco Bay for growth and release as a limited sport fishing resource which does not now exist. Cooperative Extension engineering and fish disease expertise contributed to the experiment; the Tyee Club furnished $6,000 for pen construction; National Marine Fisheries Service maintained the facility and fed the fish, and Fish and Game, of course, provided the stock. Survival was excellent and growth exceeded expectations based on similar work at Puget Sound, Washington. Proof of the pudding will be next year's angling results by sport fishermen in the Bay.

The Ventura County artificial reef for sport fishing enhancement, established a year ago as an advisory project, was carried into a second phase by County contract with the Fish and Game Commission and Wildlife Conservation Board to expand the reef. The County also is preparing a contract with Marine Advisory Programs to monitor fisherman use and local economic impact of this development.

Reefs workshop for fishermen

The Marine Resources Specialist prepared a 7-½-minute slide-tape presentation of the artificial reef project which has been requested widely. He and Ventura County's

Cooperative Extension-assigned marine advisor exhibited this at the International Artificial Reefs Conference in Houston. He also presented it and conducted a reefs workshop for sport and commercial fishermen in Humboldt County at the request of their associations.

The statewide 4-H Youth programs of the University of California were enthusiastic in expansion of marine science projects. For their use the Marine Resources Specialist and Staff Research Associate prepared a series of 20 publications, project guides, bibliography and informational leaflets. A Marine Science Conference for 4-H Youth held in Humboldt County was well attended; reception of this field conference resulted in plans for holding them in four locations next year which will give basic marine science understanding to several hundred young people.

The Marine Advisory Program newsletter audience has grown significantly, reaching about 1500 monthly. Incorporation of Seafood Technology subject matter is responsible for some of this increase, particularly among the State's seafood processing and handling industry.

PASGAP post at UC

The UC Marine Advisory Program Coordinator was selected by the Pacific Sea Grant Advisory Program to chair that coalition beginning March 1, 1974. PASGAP consists of eight universities, the three Sea Grant program schools in California plus those in Alaska, Washington, Oregon, Hawaii, the University of British Columbia and three Pacific regions of the National Marine Fisheries Service. This affiliation, an independent project of Sea Grant, supports local marine advisory programs particularly by sharing of specialized expertise and coordination of publications.

The UC Advisory Program staff has been involved in planning assistance with National Marine Fisheries Service and California Fish and Game personnel for presentation of the National Fisheries Plan to the fishing industry. In other interagency cooperation, the reduced budget and restricted advisory activity policy of National Marine Fisheries Service have not permitted program expansion.

By contrast, cooperative relationships with California Department of Fish and Game in marine science advisory activities have grown significantly. There is close working rapport and planning for joint educational efforts, particularly in advisory publications.

Publications for consumers

In other ways the Seafood Technology Specialist in a half-year on the job has had noticeable impact. Consumer workshops on seafoods held in cooperation with County Extension offices and their Foods and Nutrition, Consumer Science Specialists emphasized familiarization with fish species, selection, handling and cooking and the use of exotic or underutilized species such as skate, squid, rockfish, etc. The Seafood Technologist also prepared publications on "Paralytic Shellfish Poisoning and Red Tides," "Catching, Cleaning and Cooking Squid," and "Catching and Cooking Crab." Assistance was given to seafood processors in waste disposal methodology, quality control in seafood processing, special processes for new species, use of whitening process for fresh rockfish fillets, a cooperative undertaking with the UCD Department of Food science and Technology and its Sea Grant research investigators. Contact and rapport with the California Seafood industry has quickly expanded with the statewide activities of both the Seafood Technology and Marine Resources Specialists.

Team approach and harmony

The Moss Landing Marine Laboratories and Santa Cruz County Cooperative Extension office deserve special mention for their effective team approach in presenting marine science information to the Monterey Bay area. Sea Grant Advisory Programs have assisted county planners, coastal commissions, consumer groups, sport and commercial fishermen, in fact all marine resource users. The diver's training and certification schools, diving access survey, Carmel Bay Underwater Park development study, recreational diving committee report all were strongly visible products of the Moss Landing Marine Laboratories abilities. Their research-advisory work with commercial fishermen and fishermen's workshops are blended with and supported by Cooperative Extension and the unified Marine Advisory Program programs conducted by the UC marine Resources Specialist. The Moss Landing Marine Laboratories-University of California Marine Advisory Programs effort is so completely and effectively merged that it functions as one program, which is as it should be.

Committee appointed

In an effort to approach this harmony of planning and conduct of statewide advisory

services among the three independently funded Sea Grant educational institutions in the State, the UC Program Leader appointed an Advisory Programs Planning Committee chaired by the UC Marine Advisory Program Coordinator. With University of Southern California and Humboldt State University Marine Advisory Program leaders on the Committee along with University of California and Moss Landing Marine Laboratories representation, there is continuing input in the Committee's preparation of a comprehensive plan for all California advisory programs. The goal is to maximize Marine Advisory Program effectiveness within foreseeable budget and staff probabilities regardless of institutional affiliations. A suggested statewide plan will be submitted by the Committee which has been regularly meeting during this report period by the end of 1974 calendar year.

More Effective Delivery Of Sea Grant Advisory Services

Moss Landing
Marine Laboratories
A/P-2

Thomas W. Thompson

The Advisory Services program at Moss Landing is the key to applying the results of research in the Monterey Bay Area to ensure that coastal planners are provided with a sound and useful data base in the natural sciences.

The activities of the Moss Landing Marine Laboratories Sea Grant Advisory Services program for 1973-74 may be categorized in five broad subject areas. These are: fisheries, aquaculture, coastal zone management, public education, and administration. The work accomplished during the last Sea Grant year is discussed in this context.

Fisheries program

For the first time, during 1973-74 the Advisory Services program at Moss Landing developed a program dealing with fisheries resources. In support of this program we provided information and diving services for the Monterey Seine and Line Fishermen's Union. In July, 1973, the Secretary-Treasurer of this group came to the Laboratories and to the Department of Fish and Game with a request for assistance in locating concentrations of spawning squid. At that time the research vessel ALASKA, operated by the Department of Fish and Game, was in dry dock and unavailable. The Advisory Services program was able to obtain the ST 908 from Moss Landing Marine Laboratories and executed three research cruises employing nightlights and jigs in southern Monterey and Carmel Bays in search of squid schools. In September schools began to appear in Carmel Bay, but by and large the summer of 1973 was disastrous for the squid fishery in Monterey. As a result of the failure of the fishery and of an expanded demand for squid from domestic and international markets, the Advisory Services program requested consideration of a squid research program from the Moss Landing and University of California Sea Grant College administrations, which was developed and has been funded for 1974-75. Moreover, during the spring of 1974 approximately 10 dives were executed on the squid spawning grounds by Advisory Services personnel in order to develop a record of egg laying activity in that locale.

Diving expertise

There are no resident commercial divers in the Moss Landing Harbor. Because there is an abundance of diving expertise at the Laboratories, the Advisory program provided service to commercial fishermen in clearing nets and line from propellors, replacing pieri nuts on propellors, and executing underwater surveys of hull damage on 15 occasions.

During January the Laboratories cooperated with the University of California Extension Service and the National Marine Fisheries Service in hosting a workshop on Federal tax and subsidy programs for fishermen. This workshop was attended by more than 50 people.

At the request of Dr. John Harville, Executive Director of the Pacific Marine Fisheries Commission, Dr. Thompson parti-

ST 906, on loan to Moss Landing Marine Laboratories from Scripps Institution of Oceanography, was "Borrowed" by MLML's Advisory Services program to hunt for squid schools.

cipated in a three-day workshop on the National Fisheries Plan in Portland, Oregon, in July 1974. The Advisory Services program at Moss Landing is presently engaged in dissemination of information concerning this Plan through membership on the California National Fisheries Plan Review Committee.

Aquaculture advice

During 1973-74, for the first time, the Moss Landing program began to provide extensive services to a local aquaculture firm (International Shellfish Enterprises). During 1974 this assistance took the form of searching for and obtaining information for the firm as well as putting officers of the company in touch with Sea Grant researchers doing work on problems of mutual interest. In the Fall of 1973 the Advisory Services program located three student employees for the firm, one of whom will be executing a thesis research project under the auspices of the Sea Grant Advisory Services program and utilizing the facilities at International Shellfish. This research program, developed jointly by Advisory Services personnel and scientists from International Shellfish, involves heavy metal depuration in clams (*Tapes* sp.).

Coastal zone management

During 1973-74 the Advisory Services program at Moss Landing Marine Laboratories edited and prepared for publication a book dealing with the natural resources of the Monterey Bay area and the impact of man upon those resources. This book, entitled "Monterey Bay: Natural History and Cultural Imprints" will be in print about November 1, 1974 and will be distributed to local government agencies and school libraries. It will also be available to the general public at a cost of $4.50 per copy.

At the request of the Central Coast Region California Coastal Zone Conservation Commission, Dr. Thompson chaired an ad hoc committee on diving problems within the Monterey/Santa Cruz/San Mateo County area. At the request of the Association of Monterey Bay Area Governments, Drs. Thompson and Hurley participated in a conference designed to develop a list of candidates for identification as environmentally unique lands along the tri-county coastline.

Finally, Dr. Thompson and Ms. Bloom conducted a survey of access points for recreational divers in the vicinity of the proposed Carmel Bay underwater park in cooperation with the California Department of Parks and Recreation. This survey included studies both above and below the water's surface.

Public education

During January 1974 the Moss Landing Marine Advisory program obtained the services of Mrs. Mary Jean Bilek, a public information specialist from the University of Wisconsin, who provided training in the preparation of newsletters, materials for release to the news media and the editing of scientific materials for public consumption. On the basis of this training we have been able to improve the format of the Moss Landing Sea Grant newsletter and subsequently we published three issues of this periodical. During the summer of 1974 we updated the mailing list of the publication and are presently in the process of screening recipients of the newsletter on the basis of vocation and interest so as to better serve their needs.

Members of the Advisory Services program made presentations to six different private organizations with interests in the marine environment, participated in the Saratoga High School Career Day program, and presented a two-day workshop on oceanography for diving instructors in cooperation with YMCA and NAUI during July of 1974. This workshop was attended by 22 people who were subsequently asked to critique the program. The response on the evaluation sheets was unanimously favorable and has resulted in a request for further workshops forwarded to the Sea Grant administration via the State Advisory Committee on Sea Grant.

On July 5, 1974 the Advisory Services program presented an hour-long television show dealing with a Moss Landing Sea Grant research program on MPTV (Channel 13 Monterey). In conjunction with this television program we prepared a documentary film dealing with a joint Sea Grant-California Department of Fish and Game cruise, executed during the month of June.

Internal administration

The Advisory Services program at Moss Landing is a joint venture with the Cooperative Extension Service for Santa Cruz, Monterey and San Mateo Counties. The Extension director for Santa Cruz County, Mr. Ronald Tyler, has been extremely important in strengthening this cooperative relationship and has played an instrumental role in designing the Sea Grant Advisory Services program in the area for 1974-75. During October 1973, at Mr. Tyler's request, the Laboratories conducted a lake survey on a large farm reservoir just inshore from Ano Nuevo Point. The survey indicated that the lake had potential for recreational fishing, particularly if stocked with a combination of large mouth bass, catfish and red eared sunfish. A written report was prepared for the Cooperative Extension Service which described physical and chemical characteristics of the lake, biology and hydrography, and suggested management procedures.

In addition to cooperating with the University of California's Extension Service in local affairs, the Advisory Services program at Moss Landing participated as a member of the California Marine Advisory Program and in the UC Sea Grant Advisory Services Planning Committee, which is attempting to develop a coherent statewide mechanism for the delivery of advisory services.

Real needs

Finally, it is important to stress that input to the Advisory Services program during 1973-74 resulted in the research programs proposed for 1974-75. This guaranteed that these research proposals were addressed to real needs of user groups in the Monterey region.

Publications and Public Advisory Services

San Diego
A/P-1

James J. Sullivan

In an age of heightened ocean awareness and occasional overdramatization of plain facts about protecting and utilizing the sea and coast, an information center is essential in documenting, disseminating and encouraging the exchange of research findings and progress reports from all sources.

During 1974, we continued publication of the bimonthly Sea Grant newsletter (Sea Grant U-California), redesigning its format and initiating efforts to coordinate the three newsletters which are published within the UC program.

Each issue of the newsletter highlights a particular project, subject area or campus, lists events of interest to researchers and notes publications and reprints issuing from UCSG research.

New logo

We designed, edited and supervised publication of the 1972-73 Annual Report which featured a new UC Sea Grant logo originally introduced on the newsletter masthead.

The "Oxygen Analysis" Marine Technician's Handbook was revised and two more chapters on the underwater camera system are undergoing editing.

An article on the Isaacs/Seymour tethered float breakwater was published in the April, 1974 issue of the NOAA Quarterly and an article on lobsters in the May-June issue of Oceans magazine discussed research being carried out at UC-Davis and under the aegis of San Diego State University.

Distribution transfer

Responsibility for distribution of publica-

tions and reprints was transferred to UC-Davis but the La Jolla office continued to approve, edit, and prepare publications for production.

Two doctoral theses were published (see References at end of Report.)

The Publications Office cooperates with the SIO Public Information Office, PIO's on other campuses, other Sea Grant publications offices, the local, state and national press and broadcast media in providing copy and photographs, arranging interviews and referring questions to the appropriate researchers or experts. In its advisory capacity, the project responds to requests from students at all levels for materials on a variety of ocean-related topics.

San Diego Law Review— Law of the Seas Symposium

University of San Diego A/L-1

Darrell Bratton

While it is impossible to speculate in the impact of the recent debate about laws governing the world's oceans, an academic law review has pledged itself as a forum to chronicle developments on this crucial international issue.

The recent United Nations conference on Law of the Sea gave rise to a number of issues and possible solutions that will have tremendous legal consequences. Our annual symposium edition has provided a leading international forum for the discussion of developing legal issues. The review's objective is to continue to provide a valuable source for publication of scholarly works on law of the sea.

Subscribers increase

The Symposium currently has over 2000 subscribers who rely on the publication for information in this often ignored area. Past efforts to increase subscriptions have proven most satisfactory and we now foresee our efforts resulting in a subscription list substantially in excess of our current circulation.

Ocean Education For the Public

San Diego A/PE-1

Donald Wilkie

A modest project to increase public appreciation of and respect for the sea and its creatures sparks a consuming interest in thousands of schoolchildren, reeducates teachers, and draws eager volunteer talent to bear the message—in buckets— to students who are unable to travel.

The primary purpose of the Aquarium-Museum is to increase the public understanding of the ocean sciences and public awareness of environmental problems through the museum exhibits, the marine aquaria, and the education program.

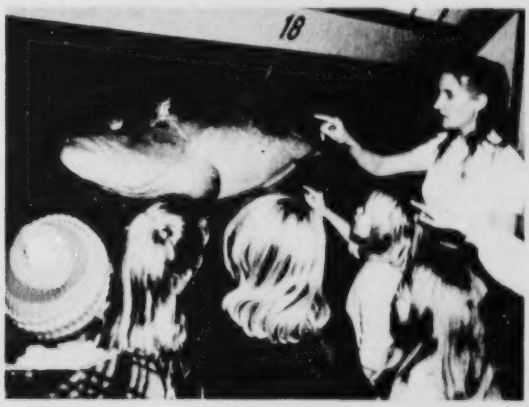
Major liaison

The Aquarium-Museum at Scripps has for many years served as the major liaison between the oceanographer and the schools of the San Diego area. A fulltime staff

member coordinates an expanded education program emphasizing the preservation of marine life and development of informed attitudes toward living things. Written education programs at different grade levels enable teachers to present an oceanography unit to their classes. Docents are trained volunteers who meet with the classes and amplify their knowledge on marine biology. For schools unable to come to the Aquarium due to the busing problem, docents now go to the classroom with a slide-illustrated lecture. Advisory services to other schools, institutions, and aquaria are a vital part of our efforts to increase dissemination of environmental aims. A high school work-study program has been organized by the assistant coordinator to train prospective marine biologists and aquariologists.

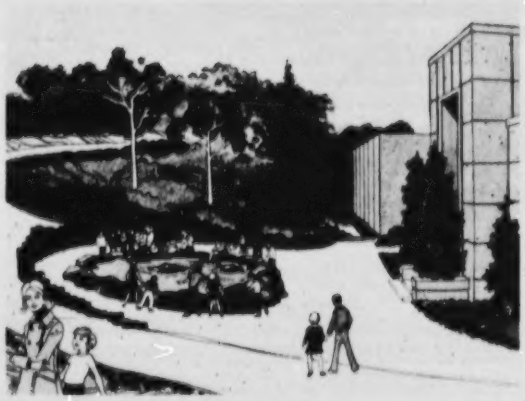
Many students

During 1973-74, 53,375 students visited the Aquarium-Museum in registered school groups to take part in our education program.



Fifty-one docents, trained volunteers from the community, conducted the education program for students visiting the Aquarium-Museum, with each docent giving one morning each week. Tide Pool Conservationists are a special group who patrol our intertidal areas during the low, weekend tides to explain conservation measures. The Outreach Program is the traveling docents who visit the schools who cannot get transportation to the Aquarium. Aquarium staff members give a yearly training series of lectures and labs for the docents, plus monthly meetings for question and answer sessions.

Advisory services are rendered to other teachers, schools, and clubs to organize oceanography courses. Last year, the federal program "Upward Bound" for disadvantaged youngsters utilized our books, films, staff, and tanks for six weeks, during which time one students was trained here as an aquarist on a shark research program. Professional assistance is given to other aquaria, such as designing new tanks for the Queen Mary in Long Beach. A continuing project is materials for the California 4-H Clubs, organized by UC-Davis Extension.



Artist's rendering of new Aquarium tidepool

Career program

Career experience program was conducted for high school students who plan careers in marine biology or aquariology. A dozen, selected students completed laboratory, classroom, and field work. Some of these students are subsequently hired at the Aquarium as apprentice aquariologists.

Junior Oceanographers Corps is a monthly lecture and field trip organization for fourth grade through high school students. Lectures by Scripps scientists augment an oceanographic cruise, a whale hunt, grunion run, plus many other field experiences.

Summer courses were offered in marine ecology for elementary, junior high, and senior high school students. These programs are self-supporting through fees charged to participants.

Outdoor tidepool

A large, outdoor tidepool will be constructed, with variable high and low tides, displaying local tidepool inhabitants. With this new exhibit, the docents will be able to emphasize even more our concern for conservation, ecological measures, and the preservation of marine life.

Ocean Engineering Data Center

J. W. Johnson

An oceanography and ocean engineering library at UC-Berkeley's Water Resources Center Archives has been reviewed with the aim of bringing it to the attention of possible users in industry, academic circles and government agencies. Two bibliographic reports have been published.

An oceanography and ocean engineering library is maintained as a separate collection at the Water Resources Center Archives, University of California, Berkeley. In this Sea Grant Project, the collection was reviewed with the aim of bringing it to the attention of possible users in industry, academic circles, and government agencies. With the funds provided, two bibliographic reports were published:

Ocean and water resources engineering reports, College of Engineering, University of California, Berkeley, Michael Poniatowski. Berkeley, University of California, Water Resources Center Archives, May 1973. This compilation lists titles in those series related to ocean and water resources engineering which have been published in the College of Engineering, University of California, Berkeley, over the past thirty years.

Ocean engineering and oceanography technical literature collection, Water Resources Center Archives, Michael Poniatowksi. Berkeley, University of California, Hydraulic Engineering Laboratory, April 1974. A bibliographical listing which catalogs and indexes a portion of the materials on ocean engineering and oceanography housed at the Water Resources Center Archives.

80,000-card index

The collection, made up of technical reports and reprints, is indexed by approximately 80,000 cards. These cards were refiled, with punch-drilled holes, in standard library card catalog cases. Cards were divided into three categories: author, title and subject.

Other than the university community, users of the collection include engineering firms and government agencies.

Sea Grant Trainee Ramiro Mayor-Mora reviewed the collection for material of relevancy, suggesting areas for collection development and indicating in the technical material those titles applicable to current problems.

EDUCATION

In its early years at the University of California, the Sea Grant Program supported the development of an Applied Ocean Science curriculum, a new graduate-level emphasis in physical and biological sciences to train scientists and engineers to solve applied problems in the ocean. The program-wide Trainee project continues this style of education, while providing graduate students from a variety of disciplines with an opportunity to undertake independent research activities. A practical oceanography technician training course remains a model for introducing undergraduates to the tasks of shipboard research.

Sea Grant Trainees

J. Frautschy and
G. Shor

Graduate students are an integral part of most projects throughout the program, providing physical and intellectual power to advance research while they fulfill degree requirements and are paid for their efforts.

Graduate students are an integral part of many Sea Grant projects. Their interest in producing meaningful research results to be used in partial satisfaction of their degree requirements gives impetus and direction to completing the projects with which they are associated. Reports of independent research accomplished by these students during the 1973-74 grant year are reported under the reports of the research projects with which they were associated. Their complete reports are available from the Sea Grant Publications office (see note on inside back cover of this report.)

Education

The primary functions of the University of California are properly, education and research. Public service is considered to be an extremely important auxiliary function. The purpose of the Sea Grant Act matches closely the purpose of the university, since it also calls for education and training, research, and public advisory services. A major portion of the research of the university is carried on as an adjunct of the educational process, with graduate students carrying out the actual research under faculty guidance, with the dual purpose of performing a significant research project and satisfying the educational requirement of a master's or doctor's thesis. Many UC research projects were initiated by graduate students under the guidance of the faculty member listed as project leader of the research project. Many were initiated by a faculty member to carry out research in the area of his teaching; one or more of his graduate students have become involved in the project, have chosen a portion of it for their own thesis work, and will carry the major responsibility for completion. In other cases, students working on a Sea Grant project are acquiring the skills and experience that they will need in subsequent years in order to prepare and carry out their own thesis research. They are, therefore, the heart of the program and are acquiring their education as a primary function while performing useful applied research in marine resources as a secondary public benefit. The students listed as Trainees are not "bottle-washers"; where such are needed, employes (student or not) for this kind of work are listed under the budget of the project concerned.

Earns degree

A Sea Grant Trainee is expected to carry out a program of training and research leading to a recognized graduate degree. The program of work is arranged in consultation with a supervising faculty member and approved by the teaching department in which the student is registered. The program of research must be one that lies within the scope of the University of California Sea Grant College Program in order for a Traineeship to be awarded to the student. This means that, normally, the student will carry out a thesis project within one of the research projects proposed; in all other cases, the project must be approved by the National Office of Sea Grant as lying within its area of interest. A student maintains eligibility for a Traineeship by carrying out research diligently and making good progress toward completion of a thesis on the research topic.

In 1973-74, there were 50 Sea Grant Trainees assigned to 31 projects on eight campuses funded by the UC program. They were assigned to such diverse research areas as shellfish aquaculture, underwater engineering and underwater recreation, kelp resource management, wave motion studies, and coastal planning.

For example, a Trainee at Moss Landing Marine Laboratories helped develop a management plan for the use of Carmel Bay as an underwater recreation area.

Practical Oceanography Training for Undergraduates

Glen Flittner

San Diego
State University
T/G-1

A year's hiatus provides an opportunity to reappraise this on-the-job marine technology training course.

Since 1970 San Diego State University, in cooperation with the Scripps Institution of Oceanography, has offered a one-semester course in marine technology under the title "Practical Oceanography." Students for the course have been selected on the basis of good academic achievement and sound, basic preparation in the sciences and mathematics. They have received first-hand experience with the techniques, rigors, and technical difficulties of conducting scientific work at sea, as well as practical experience in a variety of research projects on shore. With their excellent cooperation, the program has made effective use of the unique capabilities of the Scripps Institution staff and facilities.

Because financial support was effectively suspended by the Office of Sea Grant, we did not offer the course during the 1973-74 contract year. A majority of our students work part-time in order to support their education. Thus, we felt that it was inadvisable to enroll students in the course without at least some form of wage assistance or stipend. We firmly believe that a course such as this should be open to any student who qualifies academically, irrespective of his financial situation. Attempts were made to obtain adequate funds from the San Diego State University administration to provide such wages or stipends. However, due to financial constraints no funds were available. We plan to offer the course on a limited basis during the spring term of 1975 and are continuing to seek supplementary State funds for the program.

RESEARCH

University of California Sea Grant research proceeded along some familiar paths and took a few new byways. The November 1972 passage of Proposition 20, an initiative measure to prepare a comprehensive plan for the preservation, restoration and management of California's coastal resources by 1976 high-lighted urgent requirements for diverse factual information on the coastal environment as well as requirements for addressing unresolved coastal zone issues. In consequence, projects have been inaugurated in our program to respond to these needs. Many of our investigators in other projects have also contributed advice and information to the California Coastal Zone Conservation Commission to assist it in its planning effort.

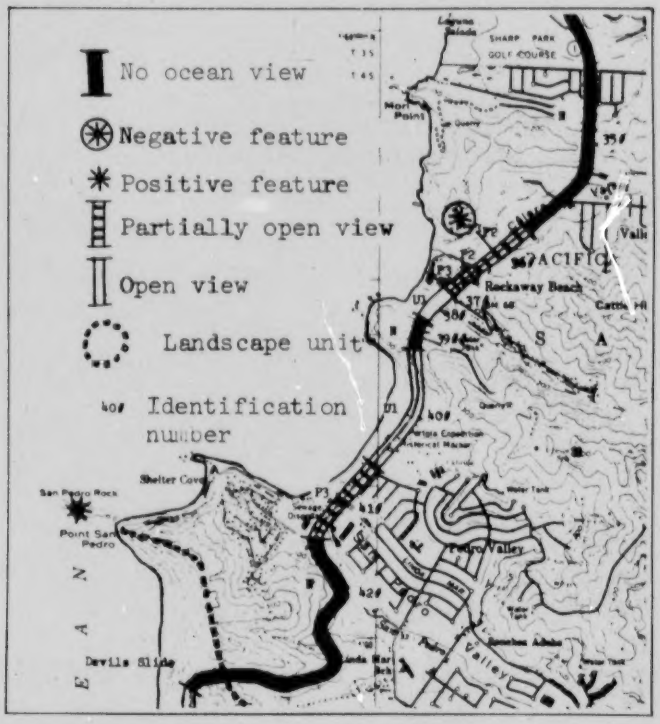
Aquaculture research efforts have continued to concentrate on *Homarus americanus*, the large-clawed american lobster. The philosophy was adopted that in-depth knowledge of the biological, physical and economic problems of a system for culturing a single species should be developed. Prospectively, much of the experience and methodology and some of the research results on the lobster would be transferrable to other species that might become the subjects of future investigations. This approach was chosen in lieu of less comprehensive initial investigations of a number of species, some of which may ultimately become more attractive candidates for commercial production than the lobster.

Two general categories of marine products were the subjects of investigation. Food technologists explored retention of attractive color and taste characteristics in canned tuna to improve customer acceptance and an attempt was made to gain a basic understanding of the materials and processes involved in the production of "fish sauce". Other chemists explored natural "chemical warfare" in an attempt to identify useful antibiotics and compounds to control barnacles and other fouling organisms in an environmentally acceptable way.

Two ocean engineering projects focused on development of an innovative wave protection system designed to sap unwanted energy from waves and another system to extract useful energy from a wave field. Another pair of studies demonstrated engineering use of an unmanned submersible operated at depths beyond those accessible to divers and under conditions when and where use of a manned submersible would be imprudent. Special instrumentation and methods were developed for *in situ* measurement of physical properties of the sea floor.

COASTAL ZONE STUDIES

The long ocean boundary of California is now seen as a uniquely valuable resource, more susceptible to injury than its rugged "last frontier" image suggested in the past. But a dedication to preserving the environment, as voiced by the public in approving the Coastal Initiative, would be ineffectual and unrealistically emotional without scientific facts and data to indicate how and where human use and development can and should proceed. How, in fact, can the recreation diver, the builder, the beachgoer, the fisherman, the conservationist, and wild plants and animals coexist? What are the realistic opportunities for restoration? How should the coast and its resources be managed, who should make the decisions, how should those decisions be enforced, and how much exploitation can the coastal zone bear - perhaps more than expected, if the exploitation is intelligently based on knowledge.



Organizational Arrangements For Coastal Management

**Eugene Lee and
Stanley Scott**

An analysis of governmental alternatives for the future management of California's coastline is considered by the Coastal Commission to be a "landmark statement in an area of research that has . . . received insufficient attention."

The work has been pursued in two phases that have proceeded simultaneously. The first phase consisted of an in-depth interview, policy analysis and writing effort devoted to the experience and future of the California Coastal Zone Conservation Commissions, the six regional commissions, and related governments. This work enabled us to act as consultants to the California Coastal Commission staff during the year, and to prepare two successive drafts of a report entitled "Governing California's Coast," both of which were submitted to and used by Coastal Commission staff in preparation of the planning element on government, powers and finance.

In-house document

The first draft, dated May 15, 1974 was used principally as an in-house document, and also circulated to a substantial number of readers for critical commentary. The second draft, dated September 20, 1974, has been rather widely distributed by the Coastal Commission in order to stimulate thinking and discussion of the issues posed by coastal planning and coastal governance. Preparation of the third draft will begin shortly. Publication is contemplated either by the Coastal Commission, or by the Institute of Governmental Studies, or jointly by the two.

The second phase of the work has collected information about coastal planning and land use control in the other coastal states, plus a few additional ones with interesting experience in land use control or wetlands regulation. We have prepared drafts giving a fair amount of detail in the case of eight states whose experience was deemed most important. These drafts are now being reviewed by observers in the states concerned. Shorter drafts have been prepared in the case of seven other states; there are also being circulated for review by knowledgeable observers. In addition, we are preparing shorter sketches of the coastal or land use regulation experience in a third group of nine states. This work is only partially complete, and is now actively in progress.

Useful briefing

When complete, we believe this state-by-state review will provide a useful briefing document for the Executive Director and other staff of the California Coastal Commission, who requested it. Although our plans are not yet firm, the material will probably also be published by the Institute of Governmental Studies, because it may hold a good deal of interest for other states.

In addition to interviewing and consulting efforts, we have produced the following tangible but not yet finally published results: Stanley Scott, "Governing California's Coast," first draft, May 15, 1974, 80pp.; Stanley Scott, "Governing California's Coast," second draft, September 20, 1974, variously paged, but totalling approximately 150pp, with one chapter to come; state-by-state drafts on 15 states, as follows: variously paged drafts of approximately 10-15 pages for each of eight states, prepared principally by Zoe Baird, with assistance from Chuck Lewis, bibliographers (Delaware, Florida, Maine, Massachusetts, Minnesota, Oregon, Vermont, Washington); variously paged drafts of approximately 5-6 pages each for seven states, prepared by Zoe Baird and Chuck Lewis (Hawaii, New Jersey, New York, Maryland, Colorado, Louisana, Rhode Island).

Third draft

Still-to-come are the third and final draft of "Governing California's Coast" and short drafts on the coastal and land-use planning experience of nine states (Alaska, Texas, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Virginia, Connecticut).

The work begun and largely finished using principally Sea Grant funding is being continued and will be brought to a completion using Coastal Commission funding, plus funds and services provided by the Institute of Governmental Studies.

Development and Assessment Of Legally Permissible Methods for Coastal Management

Ira M. Heyman

A study at Berkeley of legal methods for managing the California coastal region keeps pace with the California Coastal Zone Conservation Commission as it moves toward development of a master plan. Major new cases of relevance suggest that the scope of permissible regulations is broader than originally estimated.

This study has provided assistance to the Coastal Commission by conceptualizing and setting forth for consideration innovative and legally permissible methods of implementing the plans and planning processes that have been emerging from the regional and state coastal zone commissions; by assuring that the plans are drawn against the framework of such means of implementation; and by devising ways for integrating the plans and implementing efforts of the regional and state commissions.

During the academic year 1973-1974, the principal investigator with a trainee who began efforts in December, held a series of meetings with Coastal Zone Commission staff and each of the Regional Commission Executive Directors, at which five areas were identified for research: (1) forms for transferring development rights; (2) property tax problems, including tax equalization methods among affected local governments; (3) forms and costs of public acquisition of selected areas on the coast; (4) forms of regulatory control and their relationship to the ways the plan will set forth desired ends; (5) means for utilizing special district powers to implement plan objectives.

The Trainee during the course of the spring completed lengthy drafts of memoranda exploring topics (1) and (3) as well as a separate memorandum relevant to topic (4) which brought up-to-date a monograph prepared by the principal investigator seven years previously for the San Francisco Bay Conservation and Development Commission on the extent to which regulatory power can be used to implement restrictions and prohibitions on development likely to be determined to be useful by the Coastal Zone Commission. There had been major new cases of relevance since that memorandum was prepared which suggested that the scope of permissible regulation is broader than it then appeared.

The principal investigator became the Vice Chancellor of the Berkeley Campus in early summer and had to cease his Sea Grant work. The memorandum updating the BCDC monograph was used by Professor Bowden of UC-Santa Cruz who took over that topic and prepared a final report for the CZCC on the contemporary extent of the regulatory power.

A lengthy draft memorandum on the relationship of the emerging CZCC plan and the means of implementing it—including permit processes, subject matters of coverage, the extent to which ultimate development choices should be delayed for later decision and means for doing this—was prepared for the CZCC by the principal investigator in the late spring. That memorandum was circulated by CZCC staff and was useful in crystallizing a variety of decisions contained in Part III of the Preliminary Coastal Plan. A final version of that memorandum will be prepared for publication during the summer of 1975.

A Framework for Identification and Control Of Resource Degradation and Conflict In the Multiple Use of the Coastal Zone

Berkeley
R/CZ-1

**Robert H. Twiss,
T. G. Dickert and
Jens Sorensen**

In order to consummate recommendations for coastal zone planning, decision-makers must receive a staggering and seemingly unending supply of statistics, studies and reports on tested and proposed procedures for development. The Berkeley team has compiled bibliographies, reviewed elements in the state's master plan, and inspired the U.S. Geological Survey to plan to utilize an approach similar to the impact identification networks developed under Sea Grant.

For review purposes our work program of 1973-1974 can be divided into six areas of activity. The first five activities were designed both to provide direct assistance to the California Coastal Zone Conservation Commission (CCZCC) and to develop methods applicable to other states engaged in coastal zone management programs.

CCZCC involvement

Our involvement with the CCZCC dates from shortly after the organization of their planning staff in February 1973. We have dealt primarily with the state level commission staff.

Sea Grant trainee, Charles Schwarz, researched literature on anadromous fisheries, coastal soils, coastal flooding, and the relationship between beaches and sediments derived from coastal watersheds. Reports prepared on these topics were directly incorporated into the Commission's plan element on Coastal land Environment (the coastal plan has been divided into eleven component parts or "elements"). A literature search was also conducted on unconventional sources of energy (wind, geothermal, solar, tidal) for the plan's element on energy.

Preliminary drafts of coastal plan elements were reviewed and comments given to the Commission staff. Particular attention was given to the elements on: Appearance and Design, Marine Environment, Coastal land environment, and Recreation.

Our research library on coastal zone management and planning, developed during the last two years, has been expanded by approximately 800 documents and 1,150 citations for a total of approximately 2,200 documents and 2,700 citations. The library has been used by the staff of the coastal commission, conservation groups, and students. The second edition of the coastal zone management bibliography is being prepared from the citations in the library plus relevant citations in the libraries of the Pell Marine Station (Sea Grant Depository), U.S. Office of Coastal Zone Management, Florida Coastal Co-ordinating Council, and Scripps Institution of Oceanography.

Analyzing scenic resources

A method for analyzing the scenic resources was developed for the Appearance and Design element of the coastal plan. The staff of the Commission has indicated that this method will be used by the Commission to identify, inventory, and evaluate the lands visible from the coastal highway.

The research team has concentrated its efforts in the "intensity of development" element. The objective of this element is to determine the type and intensity of development that will be permitted to locate within the coastal zone management area. A brief paper we have prepared outlines a process that the coastal commissions may use to develop area-wide plans. The process provides both a means for controlling the cumulative impact of development and a framework for coordinating the Coastal Commission's policies with the planning and management activities of local government, regional organizations and state agencies.

Impact identification

The environmental impact identification networks developed during the previous three years of research were reviewed and tested by the U.S. Geological Survey (RALI Program) for application to the preparation and review of impact statements as mandated by the National Environmental Policy Act of 1969. The Geological Survey envisions using an approach similar to the impact identification networks developed by Sea Grant research.

Design of a Computer Automated Map—Intersection Methodology for Project Review, Plan Development and Policy Testing In the Coastal Zone

Santa Cruz
R/CZ-16

James E. Pepper

A shift in emphasis, both in the statewide resource use debate and within UC-Berkeley's coastal zone study, led the way for this map-intersection information project to develop a set of resource/impact interrelationships for testing and evaluation of its computerized system.

This pilot project was designed to develop and test the application of a computerized map-intersection information system to coastal zone planning and management. A 28-square-mile study area was selected on the Santa Cruz County north coast on the basis of the high likelihood of major resource use conflicts occurring in that area. A computerized geographic data bank was constructed (12,450 1.435 acre cells) containing the following variables for each cell: elevation; slope; aspect; vegetation type; watershed; land use; road network (including dominant road direction for Highway 1); land ownership; and four state park land acquisition alternatives.

Existing data

A survey and compilation of existing mapped data indicated that available data was of highly variable quality and that data on soils and geology was too general for application to the system. Thus the reconnaissance and construction of the data bank was initially limited by both the availability and quality of data.

Two additional unforeseen events significantly altered the immediate utility of the project. First, the major resource use conflict issues (*i.e.*, urbanization, residential development) identified in the study area became dormant as the strong development pressures (present at the start of the project) were effectively removed through a combination of local and state politics. Second, the proposed acquisition of north coast lands for a State Park has further altered the resource conflict issues upon which the project was initially based.

These two shifts required the formulation of hypothetical issues in testing the utility of the system. Four such resource-use conflicts have been identified for purposes of testing and evaluating the system, namely: second home development; recreation (both shoreline and upland); coastal agriculture; and scenic preservation.

Shift in emphasis

A shift in emphasis within the UC Berkeley Sea Grant Project R/CZ-1 also affected the development of this project. As the Berkeley group moved to policy research in support of the State Coastal Zone Commission agenda the linkage between the two projects was removed. As such the map-intersection project requires independent development of resource/impact interrelationships prior to testing and evaluation of the system.

Although these changes have required a significant research adjustment, a substantial data bank and software library has been developed for demonstrating methodology. Software programs include: spatial and quantitative data verification; topographic analysis; path sequential visual analysis; modification and updating of data files; and a series of evaluation/intersection routines.

Completion of project

Completion of the project is anticipated by June, 1975, with publication of two research papers; *Procedures for the Development of a Computer-Automated Geographic Information System for Coastal Zone Planning and Management*, and a paper on the application of a computer-automated information system to resolution of resource-use conflicts in the coastal zone. Draft sections of both publications are complete. Finally, having made appropriate adjustments to the changing research context, the project is progressing toward the objectives and goals set forth in the proposal and project summary.

Monitoring of Pollution Parameters In San Francisco Bay

Berkeley
R/CZ-12

Pat Wilde

Though most formal work had been completed, a Trainee continued to develop a seawater analysis method to monitor pollution parameters in San Francisco Bay.

Our objective is to develop a sea water analysis method which will give continuous, *in situ*, measurements of some potentially dangerous trace elements in both complex and ionic form. These elements include lead, mercury, zinc, cadmium, copper, chromium, and bismuth. Electrodes measuring these elements and their complexes will be designed for eventual use in the Berkeley towed environmental monitor.

The method, anodic stripping voltametry (ASV) has several advantages over present laboratory analytical methods (Ellis, 1973, p. 1731), the prime ones being: 1) sensitivity - trace elements with a concentration as low as 1.0×10^{-10} molar have been detected; 2) simplicity - once the ASV system is working properly, measurements can be made quickly (five minutes) and easily; 3) species characterization - the types of species, free or in complex form can be measured.

Controlled conditions

Because of the sensitivity of ASV it is necessary to do the analysis under controlled conditions in order to eliminate the "noise" caused by residual and polarizing currents. The solution is stirred at a constant rate, held at a constant temperature, and nitrogen is bubbled into the analyzing cell. At first we felt that these controls would be impractical for *in situ* measurements and experiments were performed without them, but the "noise" level was so high that it was difficult to make quantitative measurements.

We are now using the necessary controls in the laboratory and are analyzing solutions with varying concentrations of copper, lead and mercury (Perone, 1965, p. 9). We will expand the laboratory analysis to the other trace elements and will adapt ASV for *in situ* marine analysis. Some of the laboratory controls will be eliminated so the equipment will be more practical for shipboard use. A series of electrodes will be developed, each one timed for a different element, and these electrodes will give continuous measurements for the group of trace elements. Concentration gradients can be determined and a continous monitoring program can be established to see if concentration levels reach dangerous limits. A sampling cell with pumps is being developed, and the practicality of adapting derivative, pulse, and AC polygraphy for *in situ*, continuous, ASV measurements is being investigated.

Legal Techniques For Marine Resources Management

Santa Cruz
R/L-2

Gerald D. Bowden

What use is a noble idea if the public can't be convinced to implement it? There is the potent force of public pressure through consensus but legal scholars suggest implementing the coastal plan through regulation acquisition and tax incentives.

For nearly two years the California Coastal Zone Conservation Commission has been embarked on a coastal planning effort which is unprecedented in American history. One of the most difficult problems facing the Commission is how to carry out the plan once it is adopted by the Legislature. This is at once a legal and a political problem. The task of this research effort was to separate the legal from the political problem and to explain the various legal devices available for carrying out any plan that may emerge from the political process.

The best way to control any form of human conduct is through public pressure resulting from a widely shared public consensus. But since the legal process is incapable, acting alone, of using this potent force one must consider less powerful methods. These are public regulation, acquisition, and tax incentives.

In the course of this research project three

papers were written explaining each of these legal tools, their strengths, limitations, and possible uses in coastal plan implementation. These papers will be used by the Commission in several ways. First, they will be used to devise an implementation component of their plan. Second, they will be used to educate public officials who must be consulted in the planning process. Third, they will be used to educate the public whose support will be needed when the coastal plan reaches the Legislature.

To serve these purposes the Coastal Commission expects to publish these three reports separately and to distribute them widely.

Recreational Resources Of Los Angeles County Coast

Los Angeles
R/CZ-13

Glen H. Egstrom

The vulnerability of underwater resources need not discourage the careful recreation diver nor preclude coastal development. A map of the nearshore world beneath the sea showing seasonal variations in topography and marine life will guide L.A. County planners and users.

For the year 1973-74 I was designated supervisor for the UCLA Sea Grant program by Dr. Glen Egstrom. In this capacity it was my responsibility to see that all facets of the program were coordinated in an integrated and cohesive manner toward the desired end. These facets included interagency cooperative efforts, volunteer diver training, Sea Grant diver training, diver supervision, protocol modification, deployment of personnel, data collection and final project report format design, subject to the approval of Dr. Egstrom.

I was directly responsible for the depth/distance correlates. I also trained other personnel in procedures necessary for making the maps in the report.

Gary Covington
Sea Grant Trainee

The Los Angeles County Coastline is presently undergoing radical changes as a result of land development and increased industrial activity. These changes have had the effect, inadvertently, of greatly reducing the availability of inshore waters and beaches to the recreational public. In an effort to guarantee adequate public beaches, the Los Angeles County Department of Beaches and its Advisory Committee have begun to establish priorities for the acquisition and development of an increasing number of public accessways and park areas. It is obvious that this coastal planning effort interfaces with a number of public and private agencies who represent a variety of vested interests. These interests are, at times, in conflict. Also, it is often difficult objectively to assess the value of beach locations due to the lack of information concerning beach conditions and the underwater milieu. This information—factual information that describes the resource—is essential to the development of the broad insight needed for successful effective planning.

Resource inventory

The Sea Grant-supported Los Angeles County Underwater Recreational Resource Inventory took place from September, 1972 to September, 1974. The purpose of the study was to determine the present state of the topographic and ecologic underwater resource along the 76-½ miles of Los Angeles County coastline.

This resource is valuable to a rapidly enlarging segment of the recreational public. Underwater resource enthusiasts are somewhat difficult to identify by number because so many agencies train and certify them. In order to provide some insight, consider the 1970-1974 growth rate in one of the largest national certifying agencies:

Year	Number of New Certified Divers
70	34,600
71	53,700
72	66,800
73	82,800
74 (1st 3 quarters)	58,000

Southern California accounts for a significant portion of these numbers. It has been estimated that there are over a quarter of a million skin and scuba divers in the greater Los Angeles area. These divers participate in sightseeing, hunting (for game and shells), underwater photography, wreck diving, and similar activities.

The survey was a joint project that involved the Los Angeles County Department of Beaches, the Los Angeles County Engineers Office, and the UCLA Sea Grant survey project. Additional assistance was provided by the Los Angeles County Department of Parks and recreation, the Los Angeles County Sanitation District Office, California Fish and Game, Southern California Coastal Water Research Project, the Commercial Diving Center, and the Leonard Greenstone Company whose vessels and equipment were donated for use on the project.

Data scarce

An initial survey of literature revealed that very little data was available on the nearshore environment and its current state. We decided, therefore, to run a series of transects to a depth of 60' or a distance of 1500 feet seaward and at 500' intervals, in the high priority areas of the coastline. These transects were to concentrate on the diversity of topographic and ecologic phenomenon. The transects were accomplished by diver teams working from the beach, following preordained compass courses, or by videotape recording or photography, working from vessels off-shore. Videotape recordings and fathometer profiles were only secondary techniques due to the difficulty encountered when using them in kelp or heavy surge. Their use in deeper water was very effective when operating from a stable platform such as the Piedra Verde, a 60' work barge that was used to run many of the transects when beach access was impractical.

Maps obtained

Large and small scale maps of the County Coastline were obtained, and a detailed aerial photographic map of the area was made available by the County Engineers office. These documents and the available literature aided in the establishment of the project priorities. High priority was assigned to those areas where new accessways and parks were most imminent, secondary priority to areas not currently accessable, and last priority to the well-established public beaches in the sand flats of the central Santa Monica bay. A total of 308 transects were completed, on the 34 beaches that were dived (out of the 43 beaches that are included in the area surveyed).

The objectives of the survey were as follows: to examine the accessibility and suitability of certain existent or potential recreational areas along the coastline; to qualitatively and quantitatively assess the environmental factors that are of interest to the recreational public; to establish a baseline for later comparative studies related to the effect of recreational activities upon these areas.

Research syllabus

A Sea Grant research syllabus was prepared to cover the data gathering process, safety procedures, and the use of special equipment and techniques. This document was distributed to our divers at training seminars, along with copies of the Research Divers Manual by Somers and the Guide to the Coastal Marine Fishes of California by Miller and Lea. Data boards with special waterproof forms were developed so that permanent records could be made with ballpoint pressurized pens. Following the preliminary training period the teams worked, conditions permitting, for approximately twenty months. It should be noted that January through February of 1973 was virtually undiveable, with fifty-seven days judged to be unworkable in our coastal waters. It is remarkable that in two years diving activity involving approximately 2000 hours of diving, no emergency situations wer encountered. Dives were conducted according to the University of California at Los Angeles and/or the Los Angeles County Department of Beaches Recovery Unit regulations, depending upon the areas and personnel involved.

Points of interest

The locations of points of interest along the transect were determined in reference to depth, station, and beach. These included such things as different bottom rock formations, plants, animals and general bottom configurations. Data was adjusted to mean sea level. Line surveys conducted by the Los Angeles County Engineers (1967, 1969, 1972) were referenced in order to obtain depth curves for the ocean bottom in the area surveyed from Sequit Point to Torrance, excluding sections of Escondido and Amarillo Beach. Depth profiles from Malaga Cove to Cabrillo were obtained from USGS maps (1963).

Two-year effort

This report is the product of a two-year research effort (involving over 1000 individual dives and 308 detailed transects) conducted to determine the underwater recreational resources of the Los Angeles County

coastline. The detailed topographic and biologic profile that is presented here includes not only the physical data, but also an evaluation of each area as to its suitability for recreational development.

For purposes of simplification, the Los Angeles County beaches discussed in this section will be referred to as north (Leo Carrillo to Topanga Canyon), central (Topanga Canyon to Redondo) and south (Redondo to Cabrillo Beach).

The northern region, with its kelp forests (generally in the 20-30' depths) is quite well suited for underwater recreational pursuits. Abundant biota and relatively clear water, especially over the reefs, combine to offer recreationists a wide choice of activities. This rich area, however, though legally public at the mean high tideline and seaward, is seldom utilized by the public. The main reason for this disuse is inaccessibility; the beach is blocked from the highway via private property, with very few public accessways.

The central section is generally a wide, heavily utilized sand beach. This area has much less to offer the underwater recreationist. Plants and animals are rarely encountered here, except occasionally in the depth range of 25-35' where the remnants of an old shoreline can be seen in the form of a low profile cobbled reef. The seasonal sand transport on and off the beach and down the coast keep this area relatively barren.

Abundance of plants and animals

The southern section (around the Palos Verde Penninsula) is generally abundant with plants and animals. Although less lush than the northern area, this headland contains a fascinating mixture of intricate topography with caves, large underwater rock formations and relatively steep drop-offs at the base of most of the points where they protrude from the beach. The coves between these points are fairly well sanded-in, but the rocks underneath provide a stable base for a large variety of red and brown algae and sea grasses. Access to these beaches is extremely difficult in most areas. The trails are either controlled by private property or are very steep and dangerous.

It is apparent that the prime resources for underwater recreation are located at the extreme ends of the county in generally inaccessible (to the land-based recreationist) areas. Ironically, it is not unlikely that this inaccessibility has contributed to the preservation of the biota in these areas. Further evidence of the exclusivity of these coastal areas can be found in a 1974 study of recreation that was conducted by the South Coast Regional Commission. The series of findings and policies, which were subsequently published, identified lack of public access as a major limiting factor to the use of the coastline.

Points to consider

As plans for increasing the recreational usage of the coastline are implemented, it appears that the following points might be considered: There is today a lengthy and bountiful underwater recreation resource along the Los Angeles County coastline. The areas which contain the bulk of this resource are currently limited in terms of accessibility. Increasing the public access would assuredly create an environmental impact that cannot, at this time, be calculated.

In keeping with this unknown environmental impact, it would be opportune to develop a resource management and conservation program which would serve several purposes: to establish biologic preserves in the northern and southern sectors, "look, don't touch" areas, to be utilized as a perpetual baseline for the ecological evaluation of the impact of underwater recreation on our resource; to provide a systematic plan for limiting predation in other sectors of the coastline, where the extensive concentration of the areas of biologic abundance appear to offer the possibility of rotating additional "look, don't touch" areas on some long-term basis; to provide for reforestation and repopulation of the plants and animals that are known to thrive in our nearshore waters, for example, abalone shells found on cobbled and broken reef areas along with remnants of kelp holdfasts throughout most of the coastlines at depths ranging from 30-50', reminders of the days before the deterioration of the bay as a suitable habitat offer hope that rehabilitation may be possible in at least some locations; to provide for the improvement of water quality in the bay, an effort fundamental to any effective conservation and management effort.

Educating the public

The recreational public must be educated to recognize the fragile nature of the resource. It is unlikely that any regulatory enforcement program could be effective, considering the extent of the coastline. This educational program must focus upon the individual's responsibility to protect the environment against practices which would result in the destruction of the resources.

The areas which appear to have good potential as preserves are the San Nicholas Canyon area in the north and the entire Portuguese Cove area in the south. Both of these areas have highly controllable access and are presently well populated with diversified biota.

Monograph published

A 285-page monograph was published which provides a detailed description of the work which was accomplished. This document describes the approach used in the research and provides topographic and biologic data on each of the 308 transects which were studied.

An Experimental Study Of the Tomales Bay "Sneaker Wave"

Berkeley
R/CZ-15

Hugo B. Fischer

A "sneaker wave", which may not deserve its terrible reputation, has nonetheless caused fatalities at the mouth of Tomales Bay. After studies in the field and in a tidal model, questions about its nature remain unanswered.

The purpose of this project was to study three possible causes of the "sneaker wave" which has been responsible for a number of fatalities at the mouth of Tomales Bay. The causes proposed were reflection and refraction of ocean swell, formation of a tidal bore, and formation of antidunes. The study was to be primarily by means of a tidal model, supplemented by as many field observations as possible within the limited resources of the project.

Not a tidal bore

We have concluded that the "sneaker wave" is not a tidal bore in the usual sense, nor is it caused by antidunes. The second conclusion is based on lack of observation of antidunes at times when they should have occurred, *i.e.*, when the flow was clearly critical. It remains possible, however, that sometimes the sand supply is sufficient to permit the formation of antidunes, and sometimes not. It is also possible that there is no "sneaker wave", only inexperienced or careless boaters caught in obviously dangerous conditions. We have seen conditions in which the sea seemed remarkably calm and safe, and then critical flow and breakers on the bar formed within a space of 10 or 15 minutes. We have observed a small boat have engine problems at the mouth of the bay and be carried almost to the breakers by the tidal outrush, before the engine was restarted. It is clear that the tidal velocities at the mouth are deceptively high, that waves associated with critical flow can form suddenly, and the sea swell breaks over the bar in a sometimes erratic fashion. Perhaps these dangers alone can account for the observed fatality rate.

Difficult to relate

On the other hand, some of the reports of occurrences are difficult to relate to what we have observed. For instance, the first ship to anchor at the mouth of Tomales Bay in 1775 was nearly destroyed by a massive wave which occurred two hours after high tide in the middle of the night. One mechanism we have not yet been able to confirm or deny is the possibility of seiche motion in Bodega Bay alternately raising and lowering the depth at the Tomales end, thereby causing changes in the pattern of breaking of the waves over the bar and possibly short term-tidal bores. The natural period of Bodega Bay is approximately 20 minutes; a seiche of two-foot amplitudes would be sufficient to induce a short-term bore, and probably to cause intermittent breaking of ocean swell.

During the next several months we will try to measure seiche motions in Bodega Bay. A final report and recommendations will be prepared prior to July 1, 1975. Since present funding for the project will be terminated on November 30, 1974, the extent of the report will depend on funds available for its preparation.

The project has been carried out in cooperation with the California State Division of Navigation and Ocean Development. Sea Grant Trainees Richard French and Richard Della assisted in all phases of the project.

Physical Criteria For Coastal Planning

Douglas L. Inman

Understanding of the basic physical processes that operate in the nearshore environment is essential to sound coastal planning.

Understanding of the basic physical processes operative in the nearshore environment is essential to sound coastal planning. The principal objective of this project has been to study coastal processes by making definitive field and laboratory measurements which provide insight into these processes which can in turn be used in formulating meaningful criteria for coastal planning. In order to accomplish this objective the Shelf and Shore (SAS) system for instrumenting the nearshore environment was designed and is continually being perfected by the Shore Processes Study Group at Scripps Institution of Oceanography. This data acquisition system is capable of the simultaneous measurement of wave, current and other physical paramenters frum up to six different stations in coastal waters and is linked to a mini-computer for the rapid processing and analysis of data as it is acquired. Results of the project are developed into basic coastal planning criteria which are made available to interested individuals and agencies. During the past year planning information was disseminated by direct consultations and by publication (Inman, *et al.*, 1973; Inman, 1974; Nordstrom and Inman, 1973; Nordstrom, Geehan and Inman, 1973).

SAS deployment

The basic element of the SAS system is the shelf station which is a tethered buoyant spar equipped with various sensors and a telemeter package for sending data to shore. Shelf stations have been used with other instrumentation during the past year to continue various data monitoring programs and initiate new studies. Use of the SAS system is summarized below.

Torrey Pines station

A shelf station has been deployed off Torrey Pines Beach, approximately three kilometers north of Scripps Institution for over 20 months. This station is 900 meters seaward of the beach at a water depth of 10 meters. The station is equipped with four absolute pressure sensors arranged in a line array parallel to shore and two accelerometers for measuring wave energy and direction. The wave field is measured for a one-hour period four times a day in order to provide the data necessary to compile a local wave climate. To date there have been approximately 1200 data series obtained from this installation.

Scripps Canyon station

A shelf station was placed in the head of the south branch of Scripps Submarine Canyon at a water depth of 18 meters. This station is equipped with sensors to measure pressure, temperature, tilt angle, and the current in the canyon. The installation has been operational for 14 months and has provided data from the submarine canyon under diverse environmental conditions.

Scripps station

A shelf station has been installed on the shelf immediately offshore from Scripps Institution during the past year. This station is located 300 meters seaward of the end of Scripps Pier, at a depth of 17 meters. The station is equipped with a 32-element thermistor chain, an absolute pressure sensor at the bottom, and a four-element array of pressure-temperature sensors. The pressure-temperature sensor array is arranged orthogonally on the bottom at the base of the station. Measurements of temperature fluctuations in the water column made with this sensor configuration detect and document the effect of internal waves and bores passing over the shelf. Since the installation of this shelf station in August, 1974, several 16-hour-long continuous data runs have been made. Continued operation of the station over the next year will provide a large body of data on thermal fluctuations in nearshore waters.

Scripps Pier

The installation at the end of Scripps Pier in five meters of water has been enlarged to include additional temperature and current sensors. An initial installation consisting of

a pressure sensor, electromagnetic current meter, and a thermistor chain was installed at the pier end last year and used to measure thermal fluctuations. This sensor configuration was modified to include an improved 16-element thermistor chain, a temperature profiler, two additional electromagnetic current meters, and wind speed and direction sensors. The termistor chain has fixed elements at a spacing of 30 centimeters to sample the temperature of the entire water column. A temperature profiler consisting of a single thermistor mounted on a cable that moves it up and down through the water column was also installed at the end of the pier. This sensor makes a continuous measurement of the temperature structure of the water column once a minute. Three electromagnetic current meters are mounted at 0.5 m, 2.0 m, and 3.5 m above the bottom adjacent to the profiler in order to measure the current structure at the site. Wind speed and direction are also monitored to complete the environmental measurements. Measurements are made synoptically with the shelf station immediately offshore in order to fully document the effect of internal waves shoaling over the shelf.

Fluctuations on shelf

The multiple element thermistor chain installed at the end of Scripps Pier has recorded periodic fluctuations in the temperature of the nearshore waters. Temperature fluctuations throughout the water column are characterized by the occurrence of events, times during which a significant thermal gradient on the order of, or greater than those associated with the seasonal thermocline in deeper waters exists in the water column. Temperature differences between the bottom and the surface of up to 5°C have been measured.

These measurements show: (1) that the onset of events can be very rapid, occurring during times on the order of one sec; (2) that motions exist in the water column at frequencies much higher than the buoyancy frequency which are not directly coupled to the surface wave field (Figure 1); and finally, (3) that events are likely to be strongly three-dimensional in such shallow waters. Extrapolations of observations at Scripps Pier on a worldwide scale indicate that such events could be responsible for an energy flux into shoal waters ranging between 2×10^5 kw and 2×10^7 kw.

Wave climate

The wave climate at a site off Torrey Pines

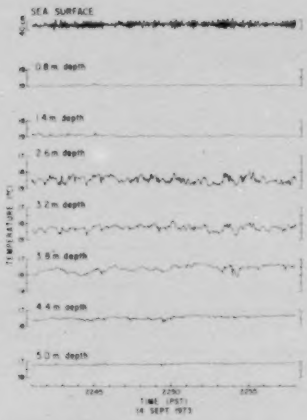


Figure 1. Seventeen-minute records of sea surface fluctuations and temperature at Scripps Pier.

Beach, California is under study using a line array of four pressure sensors roughly parallel to the straight coastline at a depth of 10 meters. The pressure sensors are linked to a shelf station that contains accelerometers, electromagnetic current meters and at times, a surface piercing staff. The data is transmitted by radio link to the shore recording station for recording and analysis.

Wave records have been taken four times daily for a period of 20 months. The recording of four records each day give an indication of the nature of variability of the wave field. During periods of wave transition, large changes in the total energy of the waves are noted between the six hour recordings. However, the full extent of the major changes in the wave field normally take place over several recordings, or a period greater than 12 hours.

The wave climate is considered in terms of both its average and specific characteristics with the year being divided into quarters for averaging wave data. Frequency diagrams of wave energy versus period for data of a particular quarter are calculated to estimate average climates. The energy recorded as a function of direction is summed over a quarter for the various wave periods. The energy-directional spectra have been investigated in an effort to characterize principle components of the wave field. From this investigation a basic bi-modal spectral form has been recognized as typical of the summer quarter (Figure 2).

Waves and cusps

A theoretical study has shown that surface waves incident on a beach from deep water can excite edge waves. Specifically, a mono-chromatic wave train normally inci-

dent and reflected on a beach of constant gentle slope is found to transfer energy to edge waves through a weak resonant interaction resulting from an instability of the incident wave with respect to perturbation by edge waves. Only edge waves with frequencies lower than that of the incident wave are excited by this mechanism. Viscous effects suggest that an edge wave with mode number zero and frequency one-half that of the incident wave (a subharmonic edge wave) is preferentially excited. The minimum incident wave amplitudes for which this resonance can occur are predicted by consideration of viscous effects. Higher order terms suggest that an edge wave with frequency equal that of the incident wave (a synchronous edge wave) may also be resonantly excited when the incident wave is strongly reflected.

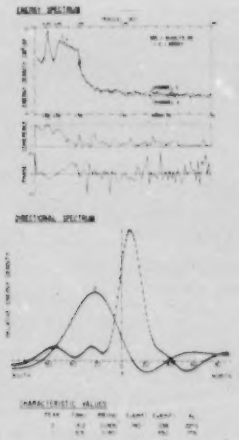


Figure 2. Energy-frequency spectrum and energy-directions spectra for waves at Torrey Pines Beach.

Strong edge wave

Experiments show that a very strong subharmonic edge wave resonance occurs on nonerodable plane laboratory beaches when single frequency incident waves are surging and strongly reflected at the beach. Smaller synchronous edge waves occur when the basin geometry or viscous effects exclude the subharmonic. Neither type edge wave is visible on the beach face when the incident wave is so large that it plunges rather than surges, incident wave energy being dissipated in the surf zone rather than reflected at the beach face as assumed in the resonance theory. This observation is quantified, and leads to a classification of beach face dynamics into reflective and dissipative systems.

Large subharmonic edge waves on plane laboratory beaches are shown to rearrange sand tracers into accumulations which resemble natural beach cusps. These edge wave induced morphologies, however, interfere with the edge wave excitation process so the edge wave amplitudes decrease as the cusps grow. Small edge waves can form longshore periodic morphologies by providing destabilizing perturbations on a berm properly located in the swash zone. In this case, the retreating incident wave surge is channelized into breeches in the berm caused by the edge waves.

Wave-formed ripples

A field study of the equilibrium configuration of oscillatory ripples formed in response to progressive waves has been completed. The ripple regime is bounded as a lower limit by the onset of grain motion and as an upper limit by the condition of sheet flow where several grain layers are in motion. The ripple geometry is controlled by the size of the sand and by the nature of the fluid motion in such a way that the ripple steepness η/λ, the ratio of the ripple height η to the length λ, stays constant at about 0.15 (vortex ripples) until just before the onset flow (postvortex ripples) when the steepness decreases rapidly to zero.

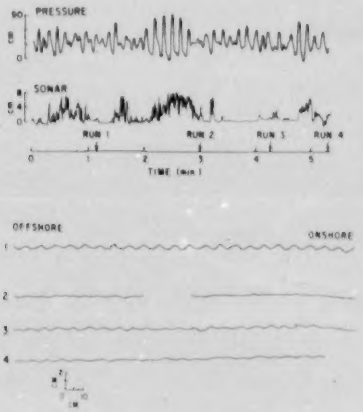


Figure 3. Field measurements of the generation and disappearance of sand ripples by wave action in water 3.4 meters deep off Scripps Pier.

The onset of grain motion, the equilibrium postvortex ripple geometry, the onset of sheet flow and the short term ripple migration have been investigated with respect to the wave-sediment interactions. The onset of grain motion was studied in a laboratory wave channel that had a special convergence section to increase the size of the waves. Analysis of the data for grain sizes between 180 and 1454 microns shows

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that grain motion commences when the dimensionless criterion

$$\frac{\gamma_s T^2}{\rho D} = 240 \left(\frac{d_o}{D}\right)^{4/3} \left(\frac{\rho \gamma_s D^3}{\mu^2}\right)^{1/9}$$

is satisfied, where T is the wave period, D is the median grain diameter, $\gamma_s = (\rho_s - \rho)g$ is the immersed sediment weight, ρ_s is the sediment density, ρ is the fluid density, d_o is the horizontal orbital fluid displacement near the bottom, and μ is the fluid viscosity.

Ripple geometry

The ripple geometry during the transition from vortex ripples to sheet flow conditions was investigated in the field using a newly developed sonic bed profiler with a vertical resolution on the order of one millimeter. It was found that the ripple steepness could be related to the dimensionless shear stress $\Theta = \rho u_m^2 / \gamma_s D$. The postvortex ripple regime commences at a Θ value around 50 and flat bed conditions occur at $\Theta = 240$.

In fine sand an equilibrium ripple geometry was produced by only a few waves and the bed could be quickly flattened by sheet flow and sediment suspension induced by a series of higher waves (Figure 3). For experiments where the rippled bed stayed intact during the entire time of observations, ripples were seen to migrate less than five centimeters. This suggests that the coupling of the ripple migration to be bottom boundary current is weak or that the flow over a rippled bottom is significantly different than the flow in the flat bed channelized models.

Ecological Studies Of the Near Shore Zone

San Diego
R/CZ-5

E. W. Fager and
Paul K. Dayton

Establishing baseline and experimental knowledge of nearshore structural and functional community relationships supports predictions of long-range effects of community perturbation from pollution, harvesting, recreational use or other intrusions that might change distribution, abundance or reproductive patterns.

Knowledge of the natural variation occurring within communities is of fundamental importance to rational management. The baseline investigations reported concern the development, pattern, and variation of several nearshore community components of commercial and recreational interest. These include, the subtidal fouling community, kelp beds, rocky intertidal, and nearshore sands.

Artificial rocks

Monitoring of the benthic community on artificial structures, some of which have been in place on the sand bottom as long as eight years, has continued. An underwater television system overlooking one concrete cube was installed to survey the block continually and to test the feasibility of "dry" observation without the limitations of diving. The transmission quality has been sufficiently high to permit identification and abundance estimates of fish which avoid divers, -e.g., sargo (*Anisotremus davidsonii*), and black surfperch (*Embiotoca jacksoni*). Significant observations include predators not normally surveyed (a double crested cormorant) and aggregations of the pelagic ocean sunfish (*Mola mola*).

The rapid buildup of the fouling community upon the artificial rocks has enabled us to follow species' changing abundances and interactions over the past year. This should allow us to make increasingly accurate predictions about the species composition, diversity, development, and eventual fate of this type of community. This study has demonstrated the value of long-term baseline studies by demonstrating the dangers of generalizing from short-term observations (for example, dense aggregations of *Cancer* crabs which appeared in summer 1972 but did not reappear in 1973 or 1974).

Kelp bed study

During the past several decades the giant kelp, *Macrocystis pyrifera*, has disappeared from some areas of the coast while it has

increased at other. A long-term program is continuing to determine natural fluctuations in the populations of kelp and its associated community.

Three kelp beds are being monitored: Del Mar, Point Loma, and Catalina Island. During the past year survivorship rates of 34%, 74%, and 57% respectively were recorded among adult plants. The survivorship varies from year to year. For example, the same figures for the previous two years were 78% and 48% at Del Mar, and 53% and 13% at Point Loma. We are investigating the effect of several parameters on mortality rate. At Catalina Island, permanent transects have been established at 5 m, 10 m, and 15 m depths. At Point Loma, very young plants have begun to be monitored along the transect; these appear to have a very high mortality rate. The mortality rate also seems to very according to the time of year. These results are preliminary; final conclusions await further sampling and rigorous statistical analysis of the data.

In cooperation with Ron McPeak of Kelco, we are continuing research to determine the effects of canopy removal on hapteral growth. Preliminary results indicate no important harvesting effect on the growth of *Macrocystis* holdfasts. Experiments to evaluate the effects of liming on the kelp bed community were prevented by the moratorium on liming declared by the Department of Fish and Game.

Cycles evident

A comparison is being made between the intertidal portion of La Jolla Preserve (Devil's Slide) and an unprotected control area (Bird Rock). Thirteen permanent 25 m^2 quadrats are monitored every two weeks. Cycles, not necessarily synchronous, are evident. Recruitment and survival of the algae within the quadrats appear to correlate primarily with physical events; heavy surf, rain, sand, and especially desiccation. Most species reach minimum standing crop during daylight spring low tides. Dependence on topographic position also appear to be significant. The occurrence of abalones and lobsters in the two areas is also being recorded. There is some evidence that their abundance is higher in the preserve area.

In the subtidal area of the preserve, thirty meters of heavy chain have been put down in an attempt to mark a permanent study area so that individual abalones, patches of *Phyllospadix*, and other macroorganisms can be followed. We are now in the process of mapping the large plants and animals along this chain. Lobster and abalone populations are also being monitored in the subtidal area. The number of abalones on our transect has fallen from 35 to 27 over the past year. The lobster population is too mobile to show any significant changes.

***Zostera* patch**

In the past year, regular visits were made to a patch of the marine spermatophyte *Zostera marina* located at a depth of fourteen meters on the edge of the La Jolla submarine canyon. Marked increases in turion density occurred during periods of calm, clear water, and were followed by gradual reductions in plant density, most probably due to wave surge and entanglement by drift algae. Survivorship of turions averaged 93% per month, but growth rates were irregular. Juvenile individuals of *Paralabrax clathratus* (kelp bass), *Coryphopterus nicholsii* (blackeye goby), and *Citharichthys stigmaeus* (sand dab) have been seen in the *Zostera* patch.

For comparative purposes, a transect was recently established in a well-developed *Zostera* bed in the San Diego Flood Channel. Well protected from physical stresses, this area harbors a diverse assemblage of animals and is regularly used by sport fishermen.

***Sargassum* examined**

The interaction of the invading brown alga *Sargassum muticum* with native plant communities is being examined. By clogging dock areas and channels, *S. muticum* has become a serious problem in some Southern California marinas. In addition, it is a new competitor for macroalgae which require space on hard substrate in areas such as the rocky intertidal.

During the past year we found a reduction in the growth rate and reproductive success of *S. muticum* relative to the previous year. Comparisons are now being made with an older population of *S. muticum* in British Columbia in an attempt to characterize adjustments in the California populations since colonization.

Sand community

Studies on the shallow water sand bottom community were begun by E. W. Fager in 1957. Two permanent fifty-meter transects established in areas where Fager worked provide a unique opportunity to study the stability of this community over seventeen years. The anemone, *Harenactis attenuata*, slightly declined from 6.48/m^2 to 4.15/m^2.

The sea pansy, *Renilla kollikeri*, seems to have undergone a much more dramatic change from 1.68/m^2 to 0.26/m^2. Other permanent fifty-meter transects are being monitored in the sand at depths of nine, 13, and 18 meters. Observations so far indicate a high turnover of the tube worm, *Diopatra splendissima*.

The abundant sand starfish, *Astropecten armatus* and *Astropecten californicus*, are important predators in the sand community. The diet of these sea stars has been evaluated from gut content analyses and compared to the relative abundance of the prey species in the environment. *Astropecten armatus* shows positive selection for the gastropods, *Olivella beatica*, *Acteon punctocaelatus*, and *Turbonilla* sp., and also for small crabs. The bivalve, *Tellina*, is far less common in the starfish stomachs than it is in the habitat. Attempts are being made to evaluate if the observed selectivity is a reflection of the predator's ability to capture prey and if it represents a selection for an "optimal" diet. In addition, the relationship between the prey available and the dynamics of the predator population is being investigated.

Artificial plants

In conjunction with our other studies, two kinds of artificial plant habitats have been created on the sand bottom near the SIO pier. An artificial eelgrass bed has been in place a few months and has mainly attracted fish which appear near any irregularity in the sea bottom. An artificial kelp bed has attracted both fish and a wide variety of invertebrates, including lobsters, crabs, starfish, nudibranchs, hydroids, and bryozoans. Comparison of faunas occupying simulated habitats with those from natural areas should yield information on the role of physical structure itself in the formation of a community. The size, number, and spacing of individual artificial plants could also be controlled in order to evaluate distributional effects of the substrate on the fauna.

Marine Ecology of the Central California Coast

Santa Cruz
R/CZ-8

William T. Doyle and John S. Pearse

The biotic diversity of the central California coast is both a blessing and a predicament—how can the conflict be resolved, for instance, between the sea otter now repopulating its ancient habitat and the commercially important abalone probably in unnatural abundance in this century; what would be the ecological effect if the commercial potential of subtidal kelp and intertidal algae were developed?

The main objective of this project was to establish an inventory of the kinds and quantities of plants and animals that occur along the central California coast in order to evaluate future changes and environmental impact from human activities, provide planners with information for use in coastal management and protection, and help identify ecologically and potentially economically important species in need of more detailed study.

Intertidal flora

During 1971-72 the project included an inventory of the intertidal flora of the Santa Cruz and San Mateo County coast. Simultaneous studies of the intertidal fauna were supported by a grant from the Association of Monterey Bay Area Governments. Sea Grant supported both the flora and fauna studies during 1972-73. By the end of the 1972-73 year, when field work for the detailed seasonal inventory was completed, a total of 19 rocky intertidal sites had been studied, 10 of which were studied for six to seven successive quarters. These sites included five in the immediate vicinity of the City of Santa Cruz where impact from the domestic sewage discharge into the nearshore environment would be the greatest; one on each side of El Jarro Point, a proposed site for a nuclear power plant; two on Año Nuevo Point adjacent to Año Nuevo Island where a unique pinniped rookery contributes seasonal natural enrichment of the nearshore waters

and where there is both a California State Park and a University Natural Land and Water Reserve, and several on the open ocean coast of San Mateo, Santa Cruz and Monterey Counties which are presumably away from areas likely to receive much concentrated human impact.

The specimens and data from the intertidal inventory were processed and compiled during 1973-74. Reference specimens of all species found are now curated in the UCSC herbarium and invertebrate collections. Duplicate invertebrate specimens have been donated to the California Academy of Sciences. The information gathered on these species (when and where found) has been compiled on cards for computer printout. Preliminary information from the intertidal survey has been provided to several governmental agencies including Association of Monterey Bay Area Governments, Department of Parks and Recreation, Department of Fish and Game and the Central Regional Coastal Commission. Publication of a Technical Report containing the information in final form should be completed in 1975.

Biotic inventory

In 1972-73, studies were begun on selected subtidal areas. In particular, a biotic inventory was done of the kelp forest of the Hopkins Marine Preserve off Point Cabrillo, Pacific Grove. This kelp forest supports a resident sea otter population, and is both fully protected and readily accessible for study. As such, it provides an excellent site for long-term detailed study of kelp forest interactions relatively undisturbed by human influences. A 73-page Technical Report resulting from this inventory was published by the Coastal Marine Laboratory of UCSC in 1974, and makes this kelp forest among the most thoroughly characterized known. In addition, two published studies on some of the more important grazing invertebrates (one on abalones and sea urchins, a second on snails) has resulted from this part of the project, and a study on kelp production and energy flow is now in progress.

Other subtidal areas studied in 1973 and 1974 were along the coast of Santa Cruz and San Mateo counties where sea otter populations are not yet established. In particular, abundances of sea urchins, sea stars, abalones and kelps were estimated off Santa Cruz Point (summers of 1973 and 1974) where there is much human diving and off Año Nuevo Island (Summer, 1973) which has had relatively little human use. These inventories will be used to estimate future changes, especially after the probable establishment of sea otter populations.

Crop assessment

Also begun during 1972-73 was an assessment of intertidal algae with potential economic importance of the central California coast. To date this work has concentrated on *Iridaea cordata* (Turner) Bory and includes seasonal standing crop assessment of bay and outer coast populations, and study of population dynamics. This work is continuing as 1974-75 Project No. R/A-10, and is described more fully by the Sea Grant Trainee involved in the project (Judith Hansen). The Trainee presented a paper at the 1974 VIIIth International Seaweed Symposium in Wales which is to be included in the Proceedings of the Symposium.

Finally, a study was begun during 1973-74 on the production and disposition of drift kelp (mainly of *Macrocystis pyrifera*) in the kelp forest of the Hopkins Marine Preserve. This work includes seasonal standing crop assessment of attached and drift kelp, estimation of the rate of export of drift kelp out of the forest, and utilization of the drift kelp as a food source by one of the main consumers in the forest. This work is continuing as 1974-75 Project No. R/A-11, and is described more fully by the Sea Grant Trainee involved in the project (Valerie Gerard).

Dr. John Pearse (left) and student team enumerating the intertidal transect near Natural bridges State Park, Santa Cruz County. The wood square represents a meter quadrat which has been subdivided into ten 10cm squares.

FISHERIES AND AQUACULTURE

In this broadly publicized and visible area of ocean research, the one most accessible to readers and viewers of the mass media, the real drama and excitement of discovery are often masked by the slow and careful procedures required to reach supportable conclusions. Marine species such as clawed lobster, not native to California, are being mass-cultured though many obstacles must be removed before market-size animals can be produced on a commercial basis. A valuable resource such as seaweed of various types is found to thrive with good management—but how to interest unadventurous Americans in consuming it? And can predictive models be devised so that the biological resources in the sea can be preserved, used, and replenished before some of them disappear past all reasonable restoration.

(*Animals*)

Development of Aquaculture Systems

Davis
R/FA-4

Robert A. Shleser

This multi-phase, multi-group project is modeling a commercial aquaculture facility with the aims of reducing costs, losses and larval mortality; improving waste control and food utilization; and developing cheaper food, more streamlined construction, and simpler operations, such as improved heating and circulation.

Maintaining the optimal environment for culture is essential to experimental and culture situations. We have taken methods for assaying levels of metabolic by-products and environmental pollutants and where possible developed automated systems which will be used to monitor the water quality in our experiments. In several cases, published methods were not satisfactory and new or modified analytical methods had to be developed. This work is a major contribution to the chemistry of seawater. These systems can be used to monitor the quality of seawater in the coastal zone as well as mariculture that may Jevelop in the coastal zone.

Toxicity established

The acute toxicity level of ammonia, nitrite and nitrate anions on *H. americanus* was established. The ammonia concentrations at which 50% mortality occurs with 96 hrs. (LC_{50} 96 hrs.) is 1.2 ± 0.1 and 1.4 ± 0.1 mg NH_3-N/l for 1 and 3 gm. animals respectively. Exposure to ammonia concentrations of five fold lower than the acute lethal levels sensitizes the animals to later ammonia exposure. A progressive necrosis of the hepatopancreas is observed. Concentrations of up to 500 mg. NO_3-N/l and 100 mg. NO_2-N/l are not lethal in 96 hrs., and no gross behavioral or physical effects are noted. These studies were done using animals hatched and reared at the Bodega Marine Lab whose diet consisted of brine shrimp.

The final breakdown product of the nitrogenous waste of the lobster and its food is ammonia which we have demonstrated to be very toxic. Since ammonia is a weak base, it will be present in equilibrium with its conjugate acid, ammonium ion, a less toxic species. The value of this equilibrium constant (the dissociation constant) in seawater has not been published. The value we have for 32 °/₀₀ has enabled us to determine the ammonia concentration that is toxic to lobsters independent of temperature, salinity and pH. We have determined this constant in ambient seawater (32 °/₀₀ and in seawater of lower salinities). Technical problems stemming from sodium interference with the pH electrode at salinities higher than 32 °/₀₀ have prevented us from establishing the pK of ammonia in seawater at higher salinities. Now that the problem is understood the manufacturers are attempting to develop an instrument to measure pH in high salinity seawater.

Water quality problems

Samples from the Davis based aquaculture systems are also sent to us when the personnel there suspect a water quality problem. Routine monitoring is now carried out using a *Technicon* Auto Analyzer II by a technician whose primary concern is the proper functioning of this machine.

A result of routine monitoring, experimental systems filter maintenance procedure was changed in order to more efficiently remove nitrogenous waste compounds. This suggestion was accepted and applied to the benefit of the system.

We are now able to monitor total organic carbon levels in all systems, as well as in ambient seawater. We have found these levels to be consistently low, around 8 ppm organic carbon, and foresee only sporadic monitoring of these levels in the systems in the future. Total organic carbon levels are determined whenever a bacterial or algal infection is suspected in a system. Dissolved oxygen, pH and salinity are monitored in all experimental systems as well as in systems where a disease problem is suspected.

Seawater sterilization

We have developed systems for ozonating seawater in culture systems and have established levels that are lethal to circulating micro-organisms. We are now evaluating the chronic effects of ozone residuals on organisms in culture. Ozone may be particularly important as a means of sterilizing large amounts of seawater where U.V. or chlorine are not useful for systems where large amounts of sterile seawater are required. This work will have application to

elimination of biofouling of power plants that are cooled by seawater and to develop foods from nutrients available from feed lot wastes or wastewater treatment plants, e.g., *Daphnia* culture (discussed under Nutrition).

In previous years we have evaluated rations produced by various manufacturers and other laboratories to provide for the nutritional needs of lobsters and shrimp. No adequate or economical rations have been developed. For these reasons we have established a nutrition laboratory to develop economic rations for aquaculture. The development of a systematic approach to nutrition of crustaceans will be a valuable contribution to the development of mariculture. Economic analysis has shown that the cost of food is a key element in the economics of lobster culture.

Food tables

An extensive literature review was conducted in order to compile available ingredient values into a standardized series of tables. The development of suitable diets for lobsters is central to the lobster aquaculture project. Attempts to define tentative designs for pilot plant situations will be limited until the design of suitable feeds is finished. A compilation of nutritional sources and their biochemical elements is the first step in composing diets. It is hoped that the nutritional requirements of crustaceans and lead to economical rations which will be used in a variety of acquaculture project.

Amino acid analyses were done by U.C. Davis in order to complete the amino acid series of tables. Using the amino acid analysis tables a computer program was developed in order that diets could be developed using various protein sources in combination which match the amino acid ratios of various experimental foods and of brine shrimp.

Diet unit

The capacity for complete extruded diet manufacture has been set up at the BML Laboratory. A suitable variety of equipment for preparation, balances, mixers, etc., and storing of the experimental diets has also beein procured. Inventories of various feed ingredients have been set up and are maintained.

Preliminary experiments aimed at determining pellet stability have indicated that more reliable methods need to be developed to determine the various aspects of pellet stability in seawater.

Daphnia, a freshwater crustacean, can be grown in large amounts; nine tons per surface acre of sewage treatment plant. We have harvested live *Daphnia*, conducted feeding studies and shown growth rate and survival to be almost the equivalent of brine shrimp. Pelletized foods are now being fabricated from *Daphnia* and algae. These will be tested during the next fiscal year.

Polyculture investigated

All species produce wastes. The treatment of these wastes can be accomplished by biological, as well as physical and chemical processes. In some instances using algae for the direct uptake of ammonia or other contaminants is more efficient and less costly than the use of standard water treatment methods. The fact that algae grown on waste products can be used as food for economically important species such as abalone, oysters, clams and brine shrimp may allow production of other economically important crops at little additional expense. The economics of these systems, polyculture, is now being investigated.

Forty-four lobsters were raised from stage 4 through stage 12 in a single 41" x 28" tank with only a 13.6% mortality. The constant presence of brine shrimp provided feed and a constant algal bloom may mask or absorb odor or newly molted individual and thus hinder detection by others. This observation offers a means of improving the survival and improving economics by reducing costs of food, space, labor in early stages of culture.

Developing criteria

Biological data were analyzed with respect to engineering criteria. Previous experimental results related to space, temperature, metabolism, and nutrition and their relationship to growth and mortality have been expressed as mathematical relationships. These relationships are the basis for criteria fundamental to any physical facility. Water flow, aeration, area and configuration, feeding rate, waste water treatment, and projected output have been calculated.

Three different facilities for rearing lobsters to marketable size in commercially significant numbers have been generated. The three concepts are stacked tank, raceway and silo. Each concept represents a technically feasible approach to large scale production given the present state of the art. The problem of unit rearing and precision

feeding have been approached in the context of each system. A workable preliminary design is now available for refinement and cost analysis.

Cost functions

We have developed a computer program that integrates the biological, physical, and engineering aspects of lobster aquaculture combining the best estimates of productivity, cost functions and design concepts. The budgetary output of this program includes the total cost per unit output and a breakdown of component costs (*e.g.*; cost of feed, labor, heat). The program includes economy of scale optimization and capital investments required. The program has been used to analyze the three design concepts using the best "state of the art" data available. A baseline cost of $3.60/500 g unit was the least costly produced in an analysis of three facilities. The program has the flexibility to absorb any technological advance and relate it directly to the cost of production. This work was done in conjunction with a related Sea Grant for the Economics of Lobster Aquaculture.

Increasing growth rate

The area of genetics offers the potential to increase the growth rate, food conversion, disease resistance, and increase mass in aquaculture. The development of techniques which will allow shortcuts in accomplishing these objectives is the primary objective of our genetics program. To this end we have established a genetics and electrophoresis laboratory to examine the genetic composition of aquatic species. This laboratory has the capability of examining many species now being examined for commercial culture. The technology worked out in this laboratory is particularly valuable because it can be used to examine the structure of natural populations and the potential for restocking species which have been diminished by over-fishing.

Our demonstration of Mendelian inheritance of cryptic (electrophoretically detectable) protein variation represents encouraging progress toward our goal of understanding and manipulating genetic components of aquaculturally desirable characters in the American lobster. This is especially so in light of recent progress in our ability to mate and reproduce lobsters successfully in closed aquaria systems. With the prospect of controlled matings becoming reality, we are looking forward to investigating such problems as the linkage relationships of our genetic markers to each other and to characteristics like growth rate, abdominal volume, disease resistance, etc.

Management of stock

In developing aquaculture technology for a commercially endangered species like *Homarus americanus*, we must also be concerned about the management of the natural resources upon which we will always rely for stocks. Effective management, in turn, depends on sound biological information. As a result of our studies two generalizations of importance to the management of the lobster fishery can now be stated: (1) *H. americanus* is subdivided into local, semi-isolated populations such that offshore stocks are distinct from onshore populations; (2) Although these local populations are on the whole genetically very similar, some genetic differences do exist and these differences should be taken into account in any effort to restock natural populations.

The UC-Davis aquaculture project draws on many skills and disciplines to develop a model system. (Left to right) Bill Splaine, BML Shop, builds the center of a lobster larvae circulator. Dr. Robert Shleser, project leader, inspects a spot prawn, part of a smaller study, utilizing technology developed through culturing lobsters. Technician Gordon Letterman collects algae which take up the waste produced by the aquaculture program. Later the plants may be fed to scallops, oysters and other shellfish. Drs. Dennis Hedgecock and Keith Nelson examine a set of electrophoretic gels mapping the enzyme patterns of lobsters.

Assessing variability

In parallel with our assessment of genetic variability in lobster populations by electrophoretic analysis of proteins, we have scored each lobster on thirty-five morphological characters. These data in conjunction with the variable genetic material are being analyzed by multivariate methods.

In attempting to assay for dehydrogenases of ethyl alcohol, lactate, glutamate, B-hydroxybutrate, hyposanthine, sorbitol, octanol, and benzaldehyde, similar zymograms (starch-gel electrophoretic patterns) were always obtained. This zymogram was obtainable even using dialized samples by incubating gel slices in 0.05 M Tris-HCl, pH 8.6, and nitro blue tetrazolium (NBT) alone. We are unaware of any reports concerning such a tetrazolium staining reaction that does not require coenzyme and PMS. Because benzaldehyde enhanced the staining reaction, particularly of the most anodal bands, it was routinely employed to demonstrate the entire zymogram. In the absence of further biochemical characterization, we have arbitrarily designated this "enzyme" "tetrazolium reductase". One of the four zones of activity showed variability which fit a simple genetic model.

Uniting disciplines

The area of physiology unites many disciplines. The effects of temperature, water quality, food, space, and other physical parameters on growth and survival are the domain of physiology. It is not possible to understand disease or nutrition without establishing criterion for environment and a healthy lobster.

This laboratory will have general application to examining the effects of temperature on growth, reproduction, and nutrition work is in progress to establish the utility of thermal effluent from power plants or other sources of warm water.

Results show that optimal growth in lobsters occurs in the 21°-24°C range. The upper chronic lethal level is 28°-29°C. This is significant to the geographical scope of possible culture sites. Some tropical temperatures are above the optimal temperature and may seasonally exceed the lethal limit. The data also permits refinement and confirmation of preliminary systems analysis temperature/growth relationships.

First mating on West Coast

Several dozen lobsters have been bred. Four females have extruded eggs and are currently developing normally to hatch. These are the first animals to perform the complete reproductive process in a west coast laboratory. If preliminary results hold, approximately two-thirds of our laboratory matings should produce progeny. The progeny of known parent lobsters will be subject to genetic analysis and comparison to parental genotypes by the genetics group.

The manipulation of egg development by means of temperature control has been routinely achieved. Hatching date is precisely predicted and controlled by this technique so that hatching is possible yearly throughout the year and has actually occurred in every month from October to August at the Bodega Marine Laboratory and the Davis laboratory.

Preliminary studies reported last year showed that lobsters grown in small enclosures diminished their growth rate long before space became physically limiting. Work during this year has quantified the relationship of space to growth for juvenile lobsters. These results were critical in establishing the area required for operation of the physical plant.

Freedom from disease

Unless animals in culture are absolutely free of disease, it is impossible to conduct studies on foods or physical systems. The establishment of criterion for healthy animals makes possible the work in other program areas. It is the domain of this program in conjunction with the engineering group to design systems and establish methods for the elimination of pathogens and prevention of disease epidemics. The detection and identification of disease organisms is part of this program.

The first of these fungi *Haliphtoros melfordensis* is responsible for a mycosis in juvenile animals, particularly in stages 5-15. This fungus penetrates the chitinous material of the exo-skeleton and invades primarily gills, and adjacent tissues, the hepatopancreas is only rarely involved. The organism has been isolated in pure culture on standard laboratory media. Without proper management procedures this disease can destroy an entire colony. No satisfactory fungicidal agent has been found to date, but good management procedures usually minimize losses due to the disease.

Lagenidium sp. was the tentative identification of the second Phycomycete identified. Confirmation of this diagnosis has been obtained from Dr. C.E. Bland at East Carolina University, Greenville, N.C. Species identification has as yet to be established; in

fact, the present isolate may be a new species. The mycosis is extremely pathogenic. Usually if as many as 2-3% animals (larvae) are found in a given pot, all (in excess of 90%) of the remaining animals will be dead within 72 hours. In advanced cases of this disease all lobster tissue will be decomposed. Often the dead animal consists of an exo-skeleton full of fungal mycelium. No satisfactory fungicidal agent has been found. Proper management can minimize losses.

Maintaining standards

It has been found that eggs which are reasonably free of epiphytic contaminants can yield good crops, provided minimum management standards are maintained. It has been found necessary in larval systems to essentially sterilize the recirculating water and to disinfect the lobster. These procedures are accomplished by treatment of the water with ultra-violet light and the animals with malachite green. The efficiency of using these agents is now being investigated.

Also, largely because of our experience with the finding of the two fungi, we have learned how to examine dead and dying animals. Tell-tale signs of the mycosis have been recognized, and in general, we are learning to know signs of a variety of maladies. Animals are routinely dissected and various organs examined very carefully. With these improved techniques it has been possible to establish in most, if not all, cases what caused death. We are continuing to develop more sophisticated histo-pathological and microbiological techniques to refine the diagnostic procedure.

We successfully responded to several serious infestations of larval stock with fungus and bacteria. Prophylactic measures proved most practical, particularly the recognition of disease early in egg development. Marginally infested larvae were successfully reared by means of U.V. water treatment, and malachite green dips as well as routine cleaning and maintenance of the hatchery system.

Special environment

Artificial seawater which is completely defined may provide an environment for conducting special research studies. Closed systems have been designed which will allow the recirculation of the same seawater for up to eleven months with only replacement of evaporated water. The development of cost effective closed systems may make possible the use of synthetic seawater for aquaculture of marine species. The activities in this program are described below.

The Davis laboratory has performed experiments useful to basic understanding of the lobster as well as evaluated long-term culture in closed systems utilizing artificial seawater. Temperature manipulation of broodstock and an extensive series of food trials were performed in closed systems at the inland laboratory. Also, the redundant systems in Davis and Bodega gave us an added insight into the nature of larval infestations. Since the closed system animals were isolated from the Bodega stock and seawater we were able to make the conclusion that the infestation spread from prehatch infestation of the egg mass.

As a part of a multi-stage filtration process *Salincornia sp.*, a saltwater marsh plant was cultured in a sand growth media using lobster effluent as a nutrient. Harvesting this plant provided an alternative means of denitrifying the culture system.

Feasibility of farming

The ultimate goal of the Sea Grant sponsored program was to determine the economic feasibility of lobster farming. The accomplishment of this objective necessitated establishing costs and determining the relationships of some 120 variables affecting the economics of lobster culture. Supported by the above research efforts, these costs and relationships have been identified, and in the light of existing information, lobster farming may be economically feasible. Clearly engineering and design must be done and this relationship must be tested in a pilot scale unit. The accomplishments of these program areas are as follows.

The computer program has been used to calculate costs of various models for aquaculture. We have united the data from our research programs as inputs to the economic program.

Available resources and manpower and other inputs must be combined in the most efficient combinations. Often these relationships are not intuitively obvious. Modeling and engineering provide for a means of achieving these goals.

Economic analysis suggests that it may be possible to produce lobster at less than three dollars per pound. Work on siting thermal effluent food constituted from waste products, and engineering will lead to further reductions in cost. The construction of a pilot scale lobster farm is warranted.

Economics of Aquaculture

Davis
R/ME-1

Warren E. Johnston

A computerized budgeting model for lobster production demonstrates usefulness in assessing alternative research priorities in lobster aquaculture.

Activity on this project during 1973-74 focused entirely on developing a framework of analysis to investigate the economic feasibility for commercial culture of the northern lobster (*Homarus americanus*), and subsequent estimation of costs of production under varying assumptions, with preliminary experimental results, for alternative hypothetical production systems.

By April, 1974, the paradigm of a computerized budgeting model for lobster production was developed and an initial presentation of its construction and analytical capability, using very preliminary data, was presented to U.S. and Canadian researchers and program administrators at the North American Lobster Research Workshop in Bodega Bay.

Revision of model

Important feedback from conference participants led to a revision of the model and the preparation of the first research paper under this project which was presented to the Marine Economics section at the annual meeting of the American Agricultural Economics section at the annual meeting of the American Agricultural Economics Association at Texas A&M University in August. This paper addressed the need for central evaluation of research results—a particularly acute need in multidisciplinary research efforts—and demonstrated the use of computerized budgeting in evaluating the "state-of-the-arts" and in assessing alternative research priorities in lobster aquaculture. The sensitivity of total cost estimates with respect to operating temperature, water flow rate, feed cost, and plant size was examined using the revised model with its assumptions. A cost estimate of $7.22 per pound was the "most optimistic" estimate. Future research needs were also identified.

Computerized budgeting

Having demonstrated the usefulness of the computerized budgeting approach in the above paper, subsequent activity at the end of the 1973-74 program was focused towards better specification of important components of the model as it relates to lobster culture in confined systems. Dr. Allen, with A. M. Schuur and L. W. Botsford from Sea Grant Project R/FA-4, "Development of Aquaculture Systems," prepared a research paper for the December meetings of the American Society of Agricultural Engineers in which costs of production are estimated by a further revision of the model for stacked tank, modified raceway, and silo alternative production systems. Costs of production appear to be substantially reduced. Activity with this focus will continue in 1974-75 by members of both this project and the collaborating project R/FA-4.

Protective Measures For Lobster Aquaculture

San Diego
R/FA-7

Harriette Schapiro

As a result of studying the biology and taxonomy of the causative agent of gaffkemia, a virulent disease that attacks lobsters and burdens already costly aquaculture experiments, researchers have successfully isolated an antigen to immunize and protect the crustaceans.

During the past year, we have made considerable progress on several aspects of disease control mechanisms in lobsters. The causative agent of gaffkemia has been taxonomically controversial. We have accumulated considerable evidence relating *Pediococcus homari* (formerly *Gaffkya homari*) to the genus *Aerococcus*. Using strains of *Aerococcus viridans*, we have been able to protect the American lobster (*Homarus americanus*) against gaffkemia. Antigenic similarities between *P. homari* and *A. viridans* have been demonstrated and probably are the basis for the protective action of *A. viridans*. A tissue culture system has been developed to investigate cellular

aspects of immunity in the American lobster.

The causative agent of gaffkemia was originally *Gaffkya homari*. The genus *Gaffkya* was abolished (Editorial Secretary, 1971) and *G. homari* became *Pediococcus homari*. However, more recent DNA homology studies have demonstrated the close relationship of *P. homari* and *Pediococcus viridans* (Kelley and Evans, 1974). The Eighth Edition of Bergey's Manual will list the organism as *A. viridans* var. *homari*. To reduce confusion, we shall, in this report, refer to the lobster pathogen as *P. homari*.

Attenuated strains

One of our objectives was to develop attenuated strains for use in immunization experiments. This ultimately will lead to procedures for induction of immunity in lobsters. It had been reported that *A. viridans* was not pathogenic for lobsters. In view of their close taxonomic relationship to *P. homari*, we felt that some strains of *A. viridans* might be the immunizing agent we sought. Several strains of *A. viridans* were examined for their ability to induce resistance to gaffkemia in *H. americanus*. Prior exposure of *H. americanus* to an avirulent strain of *A. viridans* induces protection against an experimental challenge of up to 3.7×10^4 virulent *P. homari* per animal. This would be many times higher than the number of virulent bacteria that the lobsters would normally encounter in the wild or in impoundments. This is the first report of successful experimental induction of resistance to gaffkemia in *H. americanus*. However, the immunization system is extremely sensitive to variation in immunizing and challenging bacterial strains and to the physiological state of the lobster. We are continuing our investigations of these parameters and plan to publish these results shortly.

Confirms relatedness

Our results are again a confirmation of the close relatedness of *P. homari* and *A. viridans*. Since we had collected a large number of strains of both organisms, we were in a position to initiate a taxonomic study to settle some of the taxonomic problems and perhaps identify better immunogens. Using the principles of numerical taxonomy, 80 bacterial strains were compared on the basis of over 400 characters. The results have shown the close similarity of *P. homari*, the lobster pathogen, and *A. viridans*. Several strains of *A. viridans*, in addition to the ones already tested, have been identified as potentially useful in our immunological experiments. These strains will be used to improve the efficiency of our immunization process.

In concluding our previous studies of gaffkemia in the California spiny lobster, we isolated several pathogenic strains of *P. homari* from nearshore waters off southern California. Identification of *P. homari* is tedious and requires tests for pathogenicity in the American lobster. We began a serological study in hope of producing an antibody which would be of use in identifying *P. homari*. Our results clearly indicate that, in spite of a number of common antigens, all pathogenic strains of *P. homari* possess a common, unique antigen. We have also demonstrated that some *A. viridans* strains possess this virulence antigen, and these strains are pathogenic to the American lobster. Thus, it will be feasible to use this antibody system to identify virulent *P. homari*.

The immune system in invertebrates is primarily cellular. As a means of characterizing this cellular response, a system was developed for the short term maintenance of *H. americanus* hemocyte suspensions. These hemocytes are capable of phagocytizing *A. viridans* and *P. homari*.

Soluble factors

Soluble serum factors were required for *in vitro* phagocytosis. This *in vitro* system will be used to monitor the effectiveness of our immunization procedures and to study the cellular response in detail.

We have continued our services to several aquaculture groups. These groups include Ford and Van Olst, (SDSU), Shleser (UCD, Bodega Bay), International Shellfish Corporation (Moss Landing) and University of Arizona (Tucson). The Bodega Bay and San Diego State laboratories were surveyed for *P. homari*. We have worked with the International Shellfish Corporation in reducing bacteriological problems in their systems. We are currently working with the University of Arizona aquaculture group on disease problems in shrimp culture.

Advisory function

We have consulted with the California Department of Fish and Game regarding *H. americanus* trapped off southern California for *P. homari* and found them to be clear of the disease.

We have, in cooperation with the Sea Grant Marine Advisory Program, published a bulletin with suggested techniques for

holding *H. americanus*. This bulletin should help wholesale and retail dealers minimize losses due to gaffkemia.

Theses Completed

Kellogg, S. K. 1974. Numerical taxonomy of *Pediococcus homari* and *Aerococcus viridans*.

Cherry, J. C. 1974. Induced immunity in the American lobster *Homarus americanus*.

Kimball, H. S. 1974. A serological study of the lobster pathogen, *Pediococcus homari*, and related bacteria.

Vandewalker, C. 1974. A cell culture system for *Homarus americanus* hemocytes.

Stock Identification and Ecology Of the American Lobster

Berkeley
R/FA-22

Mary Lou Pressick

An attempt at stock identification and definition of the ecology of the American lobster makes a valuable contribution to fisheries biology: using a permanent genetic tag.

During the period between June, 1974 and September, 1974 research was conducted at the National Marine Fisheries Laboratory at Woods Hole, Mass. and at the Martha's Vineyard Lobster Hatchery on underseas ecological survey of lobster populations, stock sampling, and monitoring juvenile releases *in situ*. Meanwhile, laboratory support was provided by the Sea Grant Program at the Bodega Marine Laboratory investigating the genetic variation of lobster populations for possible use in stock identification (see R/FA-4).

Assistance in this program was from Dr. Richard Cooper and the Manned Underseas Science and Technology dive team at NMFS, Woods Hole along with support diver Joseph Libbey of the Smithsonian Institute, and diver-research assistant Mary Anne Benton of the Department of Conservation of Natural Resources at Berkeley. John Hughes of the Marthas Vineyard Hatchery supplied juvenile lobsters, space, and equipment. The genetics laboratory at Bodega Marine Laboratory staffed by Drs. Martin Tracey, Keith Nelson and Dennis Hedgecock provided the biochemical data.

Stock sampling and survey

Lobsters were collected between October, 1973 and June, 1974 with the use of SCUBA. The collections were from Woods Hole, Mass. and Damariscotta Island off Boothbay Harbor, Maine. These were sent to the Bodega Marine Laboratory for electrophoretic analysis of allozymes.

Two transects were constructed running eastward from the Weepecket Islands located approximately 3 nautical miles east of Woods Hole, Mass. at a depth of 40 ft. Each transect consisted of a 50 m line marked off at each meter. Areas along the transect examined for lobsters were a meter on either side of the transect line which resulted in 100 m per transect. Each meter square was surveyed on a regular basis, dens were located by observing the presence of a lobster and the den marked. The den marker was constructed using a lead weight, monofilament line holding a piece of styrofoam with a number made with Dymo tape.

Lobsters were caught then marked using rubber bands placed anterior to the claw color coded for rapid future identification along with recording sex, carapace length, and position of the crusher claw. Surveys of this area resulted in information on 1) population density, 2) den occupancy, and 3) movement.

It was only possible to obtain 240 sixth-stage lobsters for this study as the Martha's Vineyard Hatchery experienced an unexpected wipeout of the larvae. Juvenile lobsters were placed in six trays consisting of 40 lobsters per tray. Each contained four habitat types constructed from stones of average diameters of .8, 1.4, 3.2, and 7.6 cm. Two trays were left uncovered, two were covered but had openings which allowed the lobsters to escape, and two were covered to prohibit the escape of the lobsters. The trays were then placed in Sengekantacket Pond, the site of yearly juvenile introductions by the hatchery. The trays were observed periodically to determine lobster behavior.

Electrophoretic analysis

The results of the electrophoretic analysis appear in a paper submitted for publication (Tracey *et al.*). These results reveal several significant finds pertinent to this study. The average proportion of heterozygous loci per

individual is 3.8%. From this information I can conclude that the level of genetic variability is too low to expect to identify individuals using protein markers. There is one variable locus, phosphoglucomutase (Pgm) that could be used as a marker to identify introduced lobsters. This could be accomplished as follows: Woods Hole and Martha's Vineyard lobsters possess the slow moving allele (Pgm^{100}) which is fixed, there are no heterozygotes so far detected in this population. In the Maine population both slow (Pgm^{100}) and fast (Pgm^{103}) alleles are present. The frequency of Pgm^{103} is .16 which indicates that a homozygote for the rare allele could only be expected to be found in 3% of the individuals in the Maine population. However, finding this rare female with eggs, or a mating homozygous pair would be extremely valuable as offsprings having the Pgm^{103} marker could be used for introductions and the survival monitored. This program is well worth continuing as we have the beginnings of what could be a valuable contribution to fisheries biology; the concept of using a permanent genetic tag.

Underseas study

The underseas baseline study for monitoring survival of introduced lobsters was successful in a number of ways: underwater techniques were developed along with providing the new investigators with experience dealing with lobster behavior and data on the population structure, density, den selection, and movement for a prescribed area. The results appear in Tables 1 and 2.

From these limited results on two transects several suggestions can be made regarding the lobster population of this area:

1) lobster densities range from 8.3 to 15.1 per 100 m^2,
2) suitable lobster dens are available of which only on an average of 25.2 to 27.5% are occupied at any one time,
3) lobsters change dens frequently, only an average of 23.3 to 44.3% of the lobsters found occur at previously marked dens.

The average lobster density is relatively constant with many dens unoccupied. This suggests that lobsters are spaced within a particular environment. There is no evidence to suggest that adding lobsters to the area would increase the carrying capacity. The carrying capacity has not been established. This area could be used in the future for introduction experiments, however, due to poor visibility a new area should be sought.

Juvenile introductions

Controlled releases of juvenile lobsters along with observations on their habitat selection, predators and competitors are potentially valuable for adopting standardized releasing techniques. These experiments also provide baseline data for future

Date	Dens Marked	Total Lobsters Observed	% Marked Dens empty	% Lobsters Occurring at Previously Marked dens	% Total Dens occupied
8-20	10	10			30.3
8-22	5	8	33.3	42.9	24.2
8-23	8	9	55.0	8.3	27.2
8-26	2	5	73.7	17.6	15.2
8-28	2	9	60.9	33.3	27.2
9-09	6	9	55.0	14.3	27.2
TOTAL	33				
AVG.	5.5 ± 3.2	8.3 ± 1.8	55.9 ± 14.6	23.3 ± 14.3	25.2 ± 5.3
8-19	15	15			27.3
8-22	13	17	19.0	50.0	30.9
8-23	6	13	53.6	31.8	23.6
8-26	7	21	27.6	63.6	38.2
8-28	1	13	40.9	57.1	23.6
9-06	10	19	13.6	75.0	34.5
9-09	3	8	65.4	21.7	14.5
TOTAL	55				
AVG.	9.0 ± 4.5	15.1 ± 4.3	44.1 ± 27.1	44.3 ± 23.4	27.5 ± 7.9

Table 1. Results from two 100 m^2 transects at Weepecket Is., Woods Hole, Mass.

release experiments with genetically tagged lobsters.

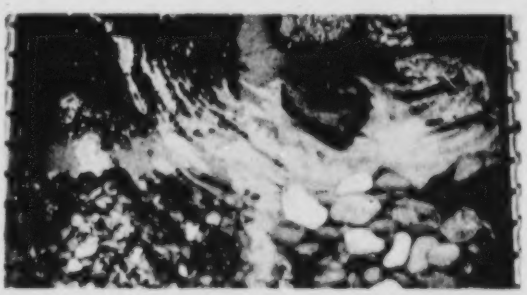
It was found that 6th stage lobsters preferred to seek shelter beneath the larger rocks even when several were crowded under the same rock. The major space competitor was a small shrimp, *Crangon septemspinosus*. Also seen in the trays which could be competitors or predators were the blue crab, *Callinectes sapidus* and the hermit crab, *Pagurus pollicaris*. Others are no doubt present but were not observed in the trays. No actual predation was observed, but *Homarus* was seen to interact with *Crangon* with the lobster gaining access to the space.

These experiments need to be continued with more diverse habitats being tested, testing the behavior of the lobsters at other stages, and with the trays more carefully constructed to achieve the desired admission and exclusion of all organisms.

Lobsters Tagged	29
female	17
male	12
Recaptured in the same den	12
Days between recaptures	6.8 ± 5.5 (range 1-16)
Recaptured in other dens	3
Days between recaptures	9.3 ± 4.6 (range 4-12)
Lobsters not seen after tagging	13(45%)
Carapace Length females	55.0 ± 12.7
Carapace Length males	56.0 ± 11.4

Table 2. Results obtained from tagged lobsters.

Lobsters are introduced into the experimental habitat before being placed underwater.



The four types of habitats are visible in the uncovered tray.

Use of Thermal Effluent in Aquaculture

San Diego State University R/FA-17

Richard F. Ford and Jon C. Van Olst

A model of university/industry cooperation, this experimental lobster-rearing project has yielded sufficient data on the beneficial effects on lobster growth of thermal effluent from coastal power plants and promises an imminent three-phase scheme for a proposed pilot-scale commercial facility.

Research on lobster aquaculture is continuing at two major marine culture laboratories developed and operated by San Diego State University. In our new laboratory at the Encina Power Plant of the San Diego Gas & Electric Company, Carlsbad, California, basic and very encouraging information has been obtained regarding the usefulness of power plant thermal effluent for aquaculture of the American lobster. We have raised larvae from the same parent in thermal effluent seawater and in seawater at our SIO laboratory heated electrically to the same temperature. We found that growth and survival were essentially the same in water from both sources. Juvenile lobsters cultured in thermally enriched water for six months at 22°C grew an average of 20% larger than those raised in ocean water at a mean ambient temperature of 18°C. Water quality analyses for toxic heavy metals, including copper, zinc, and cadmium, indicate that their concentrations are essentially the same in water from SIO and from power plant effluent. These results are very promising and suggest the advantages of

using waste heat from the power plant to enhance lobster growth are not negated by adverse side effects.

Ambient temperatures

In our laboratory at the Scripps Institution of Oceanography, several hundred lobsters have been held for over two years in seawater of ambient ocean temperatures. These lobsters, many of which are now approximately one-half pound in weight, were cultured from eggs which were hatched successfully on May 1, 1972, and were mass-reared in 10-feet-diameter swimming polls for eight months before transfer to individual culture containers. We have had an opportunity to conduct taste tests on these cultured lobsters and discovered that after two years of feeding on artificial foods, confinement in small containers, oxygen and nutrient waste stress from pump failures, and many other potential problems, the lobster meat had extremely good flavor, had good firm texture, and a pleasing white color. There was no evidence of undernourishment in the claw meat, sometimes observed in wild-caught lobsters. Analyses for heavy metal and chlorinated hydrocarbon concentrations possibly resulting from seawater pumps and lines will be done in the near future. This information is extremely encouraging because it suggests that our cultured product is equal in quality to lobsters supplied by the fishery.

Six-month survey

Recently we completed a six month growth survey of lobsters hatched in our laboratory in February, 1974, and fed on ten different natural and artificial diets which we believed might have potential as foods for commercial culture. Our results show conclusively that feeding lobsters a diet of lobster meat yields the best growth observed thus far, with our standard control diet of brine shrimp not far behind. It is encouraging to note that two other diets, which incorporate the frozen flesh and external skeleton of the pelagic red crab, *Pleuroncodes planipes*, also produced good growth. The remaining diets, developed by Purina and Louisiana State University, were substantially poorer in promoting growth. The use of pelagic red crab as a standard or supplemental feed in lobster culture may prove quite beneficial. Carotenoid pigments are present at levels as high as 21 mg/100 g in this food. The availability of the product will be increased with the establishment of a processing plant in Mexico by the Moore-Clark Company. Maximum sustainable yield for the red crab fishery has been estimated at between 30 and 300 thousand tons per year. We are continuing to test the usefulness of red crab as a potential lobster food. We have recently made arrangements to have our various diets analyzed for carotenoid pigment and protein content.

Figure 1.—Diagrammatic representation of a lobster production facility to produce 100,000 pounds per year on a four acre site.

Effects of feeding

Several of our experiments in mass rearing of Stage IV lobsters for six-month periods were surveyed for final results during 1973-74. Much of this work has emphasized the effects of feeding levels on cannibalism in mass rearing. The first experiment in which three different food doses were given showed that extreme underfeeding causes much greater cannibalism but that feeding at up to five times the normal daily consumption rate does not reduce cannibalism significantly. Based on this information, a more detailed study was devised. Although growth was directly correlated with food dose, survival was best at a feeding level of 2.5-10% body weight fed per day (dry weight to wet weight basis), and was lower on either side of this value. It appears that low food doses limit survival as expected, but that overfeeding also lowers survival, perhaps due to fouling of the culture system. Further studies are planned to verify these results and also to evaluate the effects of substrate type, temperature, and photoperiod on the survival of lobsters in mass rearing systems. Other results on the effects of substrate type, stocking density, foraging area, and substrate density are being prepared for publication. Based on our results and the work of others, we are well on our way to designing a final system for mass rearing of juvenile American lobsters.

Disease studies are continuing in conjunction with Drs. Harriette C. Schapiro and Frank Steenbergen. Their help has been

valuable to us this year in determining specific disease problems and treatment techniques. As yet, we have had no infections of our cultured lobsters with red tail disease caused by the bacterium *Pediococcus homari*.

Three-phase scheme

After several years of research on *Homarus* culture at SDSU, we believe that we have gained sufficient knowledge so that we can now propose a three-phase scheme for commercial production and evaluate this scheme on a pilot scale.

An artist's conception of how this might be adapted to a typical power plant site is shown in Figure 1. Our research has shown that larval culture is best done in the systems designed by John Huges of the Massachusetts State Lobster Hatchery. With sufficient disease treatment of the berried females and the newly hatched larvae, coupled with ultraviolet irradiation of the 22-24°C culture water, larvae stocked at densities of approximately 3,000 per container should regularly result in about 2,000 individuals of Stage IV for stocking in the second phase of the process.

Raceway troughs

These Stage IV juveniles will be stocked in raceway trough systems. This second phase, lasting approximately six months, will involve a mass-rearing or communal-rearing approach. During this time, even with high levels of supplemental feeding, relatively high losses due to cannibalism can be expected, but these losses come at a time early in the growth of the lobsters. Thus, they are tolerable in terms of labor and feed expenditures at this stage in the culture process. If the annual production required were 100,000 pounds, this mass-rearing phase might be accomplished in six raceways, each measuring 25 ft x 100 ft. Losses due to cannibalism may be advantageous because, in effect, they represent a process of natural selection which eliminates those animals least well-adapted to the artificial culture environment. The survivors grow to a larger size by consuming what we have shown to be the most nutritious food available, the flesh of other lobsters.

Individual rearing

At the end of the six-month period, each survivor of the mass-rearing phase has become so large that further losses would be economically prohibitive. Thus, at this time individual or single-cell rearing is mandatory. Several specific schemes for this labor and capital-intensive phase have evolved in the course of our work. One, the "care-O-cell" (Figure 2) consists of a matrix of perforated holding cages, which float at the surface of a large circular tank patterned after sewage treatment primary clarifiers, and which are rotated by a gear motor. As they rotate, the individual compartments pass beneath radius arms suspended over the tank. The arms supply oxygenated water, hold automated food delivery hoppers, and also allow human access for stocking and harvesting. Four-foot- and five-foot-diameter models of this system have been constructed and perform satisfactorily. A ten-foot-diameter model is under development. Present research concerns efficient waste removal and hydraulic design of the water delivery system.

Several aspects of our research have yielded data which are useful in establishing economic models of lobster production facilities so that reliable cost-benefit analyses can be conducted. We are continuing to provide information to Dr. Warren Johnston of the University of California-Davis in this regard, just as we are working with Dr. Douglas Conklin of the Food Sciences Department at UCD on the development of a suitable dry, artificial ration which is adequate for commercial lobster culture.

Papers published

Two papers were published in the journal *Aquaculture* this year. They are entitled "A recirculating culture system for larvae of the American lobster *Homarus americanus*," and "An automatic feeding device and the use of live and frozen *Artemia* for culturing larval stages of the American lobster, *Homarus americanus*," both authored by Steven A. Serfling, Jon C. Van Olst, and Richard F. Ford. Several other papers are being prepared on the results of food development, mass-rearing, and thermal effluent studies. Summaries of these papers were given at lobster research conferences at Bodega Bay, California, and Kingston, Rhode Island. Our key personnel visited all of the major lobster culture laboratories in the U.S. and Canada during the past year and information was exchanged with many different researchers. Several hundred people toured our laboratories during the year. Among them were representatives from Sea Grant Porgrams throughout the United States, the Canadian Fisheries Research Board, the University of Rhode Island, as well as scientists from

Canada, Australia, Scotland, Britain, France, Mexico, Panama, and other countries. All of these scientists were quite interested in our work and many new lines of communication have been established.

Pilot operation

During the past year we have worked closely with and received supplementary funding from a New York-based company, Homarus, Inc. The principals of this company now feel that enough progress has been made so that, in cooperation with the aquaculture group at SDSU, a pilot-scale operation incorporating the "care-O-cell" will be constructed. A suitable site and funding are now being sought. In this way, many of our culture ideas and methods will be put to the final practical test.

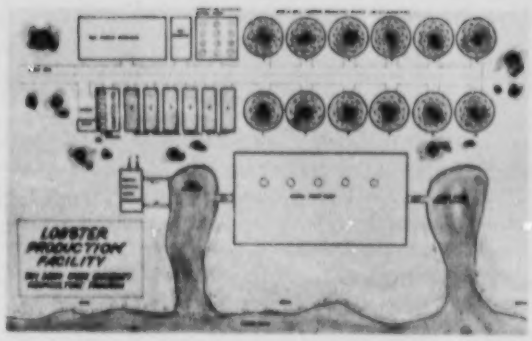


Figure 2.—Diagrammatic representation of a 100-foot diameter "care-O-cell" capable of rearing 8,000 lobsters to market size.

Berkeley
R/R-1

Oyster Mortality Problems At Pacific Mariculture Facility, Pigeon Point

Louis DiSalvo

An inquiry into potential causes of larval oyster mortality made possible the continued operation of a hatchery which otherwise would have been closed. The study provided baseline determinations applicable to future problems.

Personnel of the Naval Biomedical Research Laboratory of the University of California, School of Public Health, functioning on a two-month emergency Sea Grant (#RR-1), evaluated the culture system at the Pigeon Point Hatchery of Pacific Mariculture, Inc. to determine potential causes of larval oyster mortality. A few preliminary empirical experiments were carried out on some variables related to larval oyster growth, survival and setting ability, and a few specific measurements of opportunity were carried out on potential sources of problems.

Mortality cyclical

The program allowed continued operation of the hatchery which would otherwise have been closed. During the period of the grant, it was demonstrated that the mortality was cyclical, not appearing during the period of the grant. Successful operation of the hatchery during the period of the grant allowed for baseline determinations applicable to future mortality problems, and resulted in the establishment of the hatchery as a research station at least temporarily supported by private funding.

Results of investigations on the larval mortality problems will (a) be applied within the Pigeon Point hatchery in order to regain profitable operational status and (b) will serve as potentially valuable information for the control of larval mortality problems in other bivalve hatcheries.

Beneficial Uses of Sewage Sludge, Sewage Waste Waters, and Kelp Drift— An Aquaculture Experiment

R. W. Holmes and
R. Cooper

An algal-periphyton system, in which plants cultured in a sewage-seawater growth medium are fed to mussels and juvenile abalone, is tested for a year. The food is successfully assimilated and animal growth rates compare favorably with those obtained in local waters.

An outdoor, continuous culture system was designed to provide a phytoplankton food source for mussels, and a periphyton food source for juvenile abalone. Ten percent primary treated sewage effluent was mixed with 90% seawater (salinity 33%). This "nutrient media" was continuously fed into a 200-liter plastic drum, where periphyton were grown on glass microscope slides. The effluent from this periphyton drum was gravity fed into three other 200-liter plastic drums, where phytoplankton were grown. Initially the phytoplankton drums containing the sewage-seawater mix were inoculated with a phytoplankton tow from the Santa Barbara Channel, and allowed to sit for three days. Then continuous flow was begun, with 100 liters per day being washed out of each phytoplankton drum. The phytoplankton mix was gravity fed to other drums containing the mussels.

Periphyton biomass

Periphyton biomass was measured by suspending glass microscope slides in the periphyton drum. Algal growth on these slides began to slough off after eight to ten days. The dry weight of material on the slides after ten days' growth was 4230 mg/m^2 at the surface, 2680 mg/m^2 at 10 cm, and 2580 mg/m^2 at 20 cm. Growth rates of periphytic material as measured by chlorophyll *a* determinations were as follows: 1.79 doublings chl. *a*/day at the surface, 1.39 doublings chl.*a*/day at 10 cm, and 1.83 doublings chl. *a*/day at 20 cm.

Three different surfaces were compared as to the amount of periphytic chlorophyll *a* growing on each. Plastic slides and etched glass slides supported almost twice as much periphytic chlorophyll *a* when compared to smooth glass microscope slides.

Growth of juvenile abalone (1.80-4.28 cm. shell length) was examined under different growth situations. The abalone were divided into three groups as follows:

Group I - fed kelp (*Macrocystis* sp.); abalone kept in running filtered seawater.

Group II - fed periphyton grown on glass slides; abalone kept in running filtered seawater.

Group III - fed periphyton grown on glass slides; abalone placed directly in periphyton tank.

All groups were fed in excess. Average increase in shell length after 45 days was as follows:

Group I - 0.74 cm, Group II - 0.77 cm, and Group III - 0.10 cm.

The abalone placed directly in the periphyton tank did not grow well and several died. This possibly was due to oxygen depletion at night or toxic substances in the sewage-seawater mix.

Phytoplankton harvested

The phytoplankton was harvested from the

Table 1

Absolute and Relative Growth Rates of Mussels in the Ocean and in the Mariculture System

Growth Rate (mm./day)					
Ocean	(Standard Error)	System	(Standard Error)	System Rate/ Ocean Rate	Date
0.29	± 0.02	0.18	± .02	0.62	September, 1973
0.19	± 0.01	0.07	.01	0.37	Jan.-Feb., 1974
0.21	0.02	0.08	.02	0.38	March-April, 1974
0.35	0.08	0.23	.01	0.66	May-June, 1974
0.40	0.06	0.34	.01	0.85	June-September, 1974

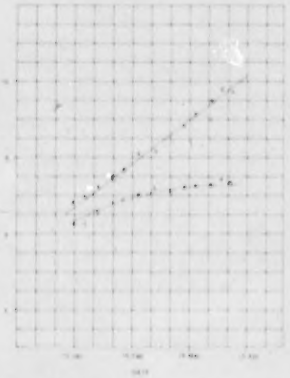
surface of the continuous culture algae tanks and fed to the mussels in a continuous flow. In the early experiments. the rate of mussel growth (measured as the change in mms. of the longest length per day) in the mariculture system was relatively poor compared to the growth rate of control groups in the ocean. Reducing the concentration of algae, increasing the oxygen concentration, and increasing the current flow in the mussel tanks produced growth rates comparable to those observed in the ocean (Table 1).

Population sampling

During this second year, Ann Child (a Sea Grant Trainee) has extended the analysis of differences in the population structure of the amphipod *Orchestia Traskiana* as a portion of her doctoral project. With the use of isozyme analysis and ecological transplantation experiments, she has found that two closely proximate populations (*e.g.*, from a freshwater stream and from a nearby ocean beach) can be markedly different genetically. More specific information on that subject is contained in her report.

Suitable techniques

A major emphasis this past year has been a search for suitable culture techniques for these animals. Floyd Dewitt used defined conditions and compared growth rate, longevity, and food adequacy for animals grown on different substrates. He also checked these parameters for animals grown on sewage sludge as a comparison. In all his cultures, however, mortality was high. This was particularly true for those animals which subsisted entirely on sewage sludge.



Growth curves for sexually mature males (top curve) and females (bottom curve). These animals had left the female brood chamber the previous June. Each point represents the average length of 15-20 animals. The same lot was measured each week.

An inexpensive stack system culture method was generally successful and holds much promise. Although mature animals which mated and produced young did not survive long after that time, their offspring did very well. At the end of a 9-month period more than half remained alive. We now use this stacked culture system routinely in our amphipod studies.

Growth rate data

Floyd DeWitt gathered specific growth rate data for sexually mature individuals (see Figure 1). From his results, it is evident that females reach a maximum size somewhere between 7 and 8 mm cephalothorax length (although larger females are sometimes found in natural populations). Males, on the other hand, continued growing and had no apparent reduction in the rate of growth in the larger size classes. It could well be that females expend their food energy intake in egg production while males expend theirs in growth.

Sex ratio phenomenon

In a 1972 publication (*The American Naturalist* 106: 321-350), we outlined the phenomenon of sex ratio being a function of size in marine crustaceans. Each species seems to have a characteristic "probability curve" which varies little with season or geographic location. In that paper (pp. 343-344, figure 20), the data for *Orchestia traskiana* indicated that females were relatively abundant in the 6-9 mm range and males prevailed in the larger size classes (see Figure 2).

The reason for the dip in the probability curve is now clear. Females in the UCSB Lagoon pond population reach an *average* maximum size of about 7.5 mm cephalothorax length as shown in Figure 1. This size corresponds closely with the center of the dip in the probability curve for that same population, as shown in Figure 2. Females of that size range apparently accumulate in the population upon reaching maturity, but males continue growing through that size range. Sex reversal need not be postulated as suggested in an earlier report (14 November 1973). Neither would it be wise, as suggested in that same report, to harvest large animals indiscriminately on the assumption they would all be replaced by females which would grow larger and become males.

Throughout the study, the experimental results have been similar. Animals died off with time at varying rates, depending upon the presence or absence of substrate

material. Survival of animals fed seaweed or newspaper was better than for animals fed sewage sludge. However, no growth could be detected for animals measured either of the two ways for any field caught animals during the course of the study.

It would seem that a defined culture in the laboratory requires some unknown factor or factors (which may make them habitat-specific as found by Ms. Child). Presumably a strain of lab-adapted animal could be developed, starting with the offspring of field-caught berried females.

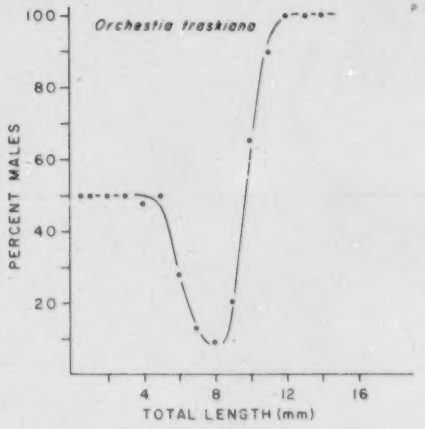


Figure 2.

(*Plants*)
Seaweed Resource Management

Santa Barbara
R/FA-10

M. Neushul

Working in close cooperation with commercial kelp harvesting firms, the Seaweed Group has carried out studies of mutual benefit to industry and academe: through inventories and experimental harvests, scientists have been able to estimate the standing crop of *Macrocystis*, rate of regrowth and plant mortality, which will form the basis of a resource utilization model for this most valuable California marine crop plant.

This past year has been very productive from the standpoint of actual work accomplished and because of the opportunities which we have had to present our work and receive the comments and suggestions of members of the international community with interest in marine algae. The aim of our program is to develop the information and techniques necessary for management, cultivation, and optimal harvesting of seaweeds in California. Our approach combines biological and economic considerations in studies of marine algae which we have identified as having actual or potential commercial value. In our studies we use both laboratory and field investigations to examine these resources.

Valuable species

One of the potentially valuable marine plants is *Porphyra nereocystis*, a California species of the algal genus which is the basis for Japanese industry, the landed value of which is over 250 million dollars/year. During the past year, we have continued our studies of this plant, and have determined the standing crop, seasonal abundance, reproductive period, and distribution of *P. nereocystis* along a 20km stretch of California coastline. We have harvested this plant, made commercial "nori" sheets from it, and evaluated the feasibility of a small-scale harvesting operation. Using this information we have determined that over 390,000 nori sheets could have been produced from the study area, with a value in excess of 23,000 dollars. Aerial photographic techniques have been used to begin a more complete resource inventory of these plants. From our studies we have also been able to formulate management concepts and guidelines which may substantially improve the extent and value of this resource. Our insight into the overseas market for *Porphyra* may be significantly improved in the near future, as Mr. James Woessner, a Sea Grant Trainee with our program, has applied for a scholarship from the Japanese Department of Education for one year's study in Japan. He is receiving the support and assistance of Dr. M. Kurogi, who is the foremost Japanese authority on *Porphyra*.

Water motion tank built

Laboratory studies of *Porphyra* have been carried out in a large water motion tank built

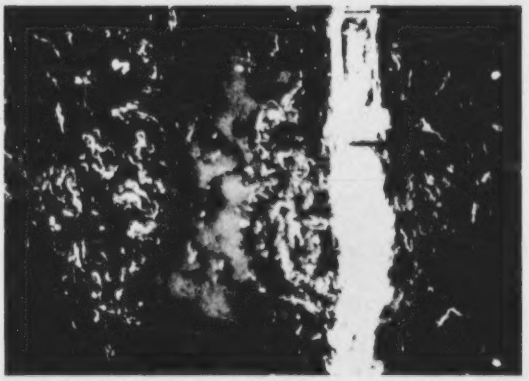
this past year. Using this tank we have obtained growth rates under various light and water motion regimes, followed regeneration of cut plants, and developed a technique for "gluing" plants to artificial substrates. We have also used the tank for studies of the agarweed *Gelidium robustum*, and while we have not yet completed extensive growth studies, we are pleased that this water motion tank enables us to maintain these plants in the lab for extended periods of time.

Our instrumentation effort, directed toward the measurement of the various physical parameters in benthic communities, is improving rapidly. We have obtained continuous light measurements by radio telemetry from our offshore site. We have sampled six different spectral regions with our multiple sensor unit, and used this data to develop a mathematical formula which allows description of the total distribution of light intensity vs. wavelength in the region of biological interest. With the cooperation and assistance of the Physics Instrumentation Program on the UCSB campus (a graduate program), we have added temperature, wave height and wave surge monitoring capabilities to our telemetry system. The total multiple sensor unit is being prepared for offshore installation.

Local species draws attention

A great deal of attention has been focused on our local species of California's most valuable marine crop plant, *Macrocystis*. Using a newly developed "water tunnel", we have investigated the productivity of *Macrocystis angustifolia* in the laboratory and in the field. These measurements indicate that the very rapid growth rates of this plant may be related to unique characteristics of its photosynthetic process, which have been reported previously in the most productive land plants, With the water tunnel, photosynthetic rates of *Macrocystis* have been measured under varying light and water motion conditions. It appears that water motion, and its effect on nutrient uptake may be a limiting factor for the present growth of populations of *Macrocystis* near Santa Barbara. Additional large-scale studies of *Macrocystis* have been conducted with the cooperation and assistance of two commercial harvesting firms—Ocean Labs Inc., and Kelco Co. We have carried out experimental harvests in two local kelp beds using the commercial harvesting vessels.

By combining the results of these harvests with aerial photographic and ERTS (satellite)



Ocean Labs kelp harvester removing a specific region of kelp canopy from the study site in Goleta Bay.

data, and extensive subsurface measurements in these populations, we have been able to estimate the standing crop and percentage of material removed by harvesting, and measure the rate of the first canopy layer regrowth. The data collected on the harvesting yields, plant spacing, density, vertical and horizontal distribution, and plant mortality will form a part of our resource utilization model for *Macrocystis*.

Results are shared

The results of our studies have been widely disseminated this year. We have presented nine papers (two by special invitation) at scientific meetings, and given lectures for a career guidance program and a group interested in marine algae as a food source. A listing of the presented papers and those in press is given in the appendix which, with the abstracts, gives additional information on our studies. We helped arrange, and conducted a meeting of the California Seaweed Group which was held concurrently with the Western Society of Naturalists meetings in San Diego. At this Seaweed Group meeting, we sought and received support for a formal invitation to the International Seaweed Symposium Committee, to hold the 9th International Seaweed Symposium at Santa Barbara.

Thanks to the provision of special travel funds by Kelco and E G.&G. Inc., five members of our group at Santa Barbara were able to attend the 8th International Seaweed Symposium in Bangor, Wales. In addition to the regular meetings, special sessions on *Macrocystis* and plant mariculture were attended. Prior to and after the symposium, members of the Santa Barbara Seaweed Research Group were able to visit many investigators in Europe. These visits were very productive, and as a result we are doing

some small cooperative studies on *Macrocystis* production and have exchanged useful information on marine telemetry. During the symposium, the formal invitation for the 9th Seaweed Symposium was extended to and accepted by the Governing Committee. The Phycological Society of America and the International Phycological Society have requested joint meetings with the Seaweed Symposium, which will make the gathering a significant, large-scale international phycological congress. We are extremely pleased to be able to bring this international conference (which emphasizes interchange between basic and applied interests) to Santa Barbara in 1977 and look forward to much fruitful intercampus cooperation in planning and having these meetings.

In summary, we are pleased with the work accomplished during the past year and look forward to integrating the results of this work with our studies in the coming year.

Professional Placement

James Cowen, Staff Research Associate, Dr. Folsom, Scripps Institution of Oceanography, La Jolla, California.

Sea floor light unit with six spectral region sensors shown during early trials before its installation on the sea floor.

Agarweed Resource Management

Donald C. Barilotti

San Diego
State University
R/FA-12

Insight is gained into the effects of environmental factors such as light, water motion and temperature, and grazing on natural populations of agarweeds with an eye toward management of the natural population.

Agar producing companies in the U. S. are now faced with either decreasing production, or establishing domestic sources of agarweed for the production of pharmaceutical grade agar. Pharmaceutical agar is a vital material for microbiological studies in hospitals and research laboratories.

This project during the past two years has been directed toward increasing domestic production of agarweeds through management studies of natural resources and mariculture studies of plants under laboratory conditions. Results of the resource management studies are now serving as a basis for recommendations to the California Fish and Game for changes in harvesting regulations and to harvesters for increased yields. Laboratory growth rate studies have provided us with preliminary information on expected yields from mariculture exploitation of agarweeds.

Regeneration studies

Studies of regeneration after harvesting indicate that regrowth of *Gelidium robustum*, the primary agarophyte for the production of pharmaceutical grade agar in southern California, is mainly due to regrowth of axes from the basal portions of the plant that attach it to the rocks. Recruitment via spores is minimal due to limited dispersal of the non-motile spores which are released in the spring of the year. Recommendations to the California Fish and Game are that the regulations be rewritten to insure that removal of rhizoidal attaching organs during harvesting is minimized.

Growth rate studies in a variety of habitats in southern California indicate that vegetative regrowth of the plants is on the order of 10 cm a year. From these growth rates a harvester should not expect to harvest an area more often than every two years if they are trying to optimize their returns. The biomass of agarweeds, contaminating organisms growing on the agarweeds, and agar content have been determined with depth and season to provide the harvester with

quantitative information needed to direct harvesting operations. Since harvesting operations for agarweeds are conducted by divers, an optimal harvest strategy must consider wave and swell conditions that might mitigate safely harvesting in shallow water where the agar yield per unit area would be highest.

Mariculture potential

Preliminary studies of mariculture potential have been conducted with *Gelidium robustum*. Disease problems characteristic of animal mariculture ventures has not been discovered, however, the plants are very sensitive to contaminants in the water. Kerosene at less than 2 ppm and copper compounds from a pump impeller not toxic to animals such as lobsters and sea urchins stop the growth of *Gelidium*.

Based on current agar prices and optimistic calculations of growth, agar content and plant densities, we estimate that one could expect a gross profit of $1,600/acre after one year regrowth on a crop of *Gelidium robustum*, and a return of $7,200/acre after two years. From this gross profit would have to be substracted (1) land costs and (2) costs associated with providing the plants with requirements such as water motion and nutrients, combating invading "weedy" species, and harvesting and drying the plants for shipment to the agar producer. One of the major problems we have in our pilot plant studies is controlling unwanted species, many of which are microscopic.

Salt-Tolerant Plants: Problems and Potentials

Davis
R/FA-13

Emanuel Epstein

Experiments on the salinity tolerance of formerly landlocked plants such as barley, tomatoes and cotton are refined to reveal that tolerance varies with each stage of the life cycle. Success would mean that seawater or a partly synthetic salt mixture could be used for crop production without the prohibitively expensive process of desalination.

The aim of this project is to increase the economic usefulness of resources that have so far scarcely been tapped for purposes of crop production: sea water and the shore environment dominated or influenced by it. The main means whereby this aim is to be achieved is breeding crop plants tolerant of highly saline conditions. While most crop species are sensitive to salt, there is no basic biological imcompatibility between salinity and plant life—hence the current attempt to combine within the same species economic utility of a crop with a high degree of tolerance to salinity, through a program of selection and breeding. Success would mean that sea water could be used for crop production without the enormously energy-expensive process of desalination.

Barley studied

During the year covered by this report, as the year before, we continued to devote the major share of the project to barley. The reasons for the use of this plant are (1) its importance as a crop (approximately 1 million acres in California in 1974); (2) the large background of knowledge of both the genetics and the salt relations of this species; (3) its known genetic variability with respect to salt tolerance; and (4) the availability, on this campus, of seed of composite crosses of barley embodying germ plasm of thousands of strains from all over the world, including extensive areas of saline soils.

We used a synthetic sea water salt mixture and raised plants in conventional nutrient solution which were progressively salinized with this salt mix. This is an extension of previous work in which sodium chloride alone was used for salinization.

Less harmful

We find that salinization with synthetic sea water is decidedly less harmful to the plants than salinization with only sodium chloride. For example, somewhat less than the sodium chloride concentration present in sea water resulted in a severe selection of salt tolerant individuals, only 5.8 percent of the plants setting seed. On the other hand, using sea water salt mix at 1.25 times the

concentration of sea water, we observed seed set in 9.2 percent of the plants.

A second important finding is that salt tolerance varies greatly with the stage of the life cycle of the barley plant. That is, a given line may establish seedlings and grow well vegetatively under saline conditions but fail to set seed, whereas another line may be sensitive at an early stage but, once over this period, may proceed to set seed under highly saline conditions. It will thus be necessary, through breeding and selection, to generate barley with a high degree of salt tolerance at all stages of its life cycle. Initial testing of selected lines for salt tolerance at all stages of the life cycle is about to begin.

Rapid test

Preliminary suggestions that absorption of chloride might be used as a rapid test for salt tolerance in barley have not been borne out by recent experiments. It appears that only actual performance in growth and seed set can serve as a reliable index of salt tolerance (see, however, below).

We have also experiments under way with tomatoes and with cotton. Seed of the Galapagos Islands tomato, *Lycopersicon cheesmanii*, was first increased, little being available, and then tested for salt tolerance in comparison with the conventional crop species *L. esculentum*. The Galapagos Islands species is considerably more salt tolerant than the crop species, and interfertile with it. This suggests that the salt tolerance of the former can be bred into the latter. (The Galapagos Islands species itself is useless as a crop, bearing very small tomatoes. Hence it can be used as a source of germ plasm to incorporate salt tolerance into the economically useful conventional species.)

Chemical and biochemical assays for mineral elements, amino acids, and other constituents are being done with barley, tomatoes, and cotton to discover metabolic indexes useful in characterizing salt tolerant strains. Assay for the amino acid proline emerges as the single most useful index so far, and the tests are being continued.

(*Fisheries*)

Toxins from Marine Dinoflagellates

Berkeley
R/FA-18a

Henry Rapoport

In this interdisciplinary, intercampus project, a UCB chemist and a UCSD marine biologist have successfully developed a simple, sensitive chemical assay for saxitoxin, the paralytic poison present in some red-tide microorganisms and also greatly restricting shellfish utilization at certain times of the year.

Our major effort during this first year of funding has concentrated on developing a simple, sensitive chemical assay for saxitoxin, the paralytic poison present in shellfish at certain times of the year. Currently, a mouse assay is used. This method is quite troublesome and time-consuming, requiring material to be sent to a central laboratory for analysis. Also, the mouse assay is insensitive and unreliable at low levels of toxicity. As a result, a quarantine is usually established on shellfish, based on past impressions, according to the calendar.

We have now developed such a chemical assay for saxitoxin and applied it to clams from Alaska and clams and mussels from the San Francisco Bay Area. Our chemical test is one-hundred times more sensitive than the mouse assay and is completely reliable at low levels of toxin. It can be easily and rapidly (about thirty minutes) applied at relatively low cost and with little training.

Dinoflagellate source

We have attempted to apply this test directly to the dinoflagellate source, *G. catenella*. Although positive results were obtained on occasion, most results were low and erratic. The explanation which is now emerging for this behavior is that saxitoxin exists in a "masked" form from which the toxic form is fully liberated only by a hydrolytic reaction. Therefore, as it stands, our chemical assay is not applicable to the dinoflagellate. We must modify it in some way in order to get reliable toxicity data. The capability of monitoring the dinoflagellate population is important since it will allow us to anticipate potential toxicity much earlier in the food chain. Also, knowledge of how this toxicity is "masked" and "unmasked" could be of potential value in public health; *e.g.*, it may be suggestive of how to

overcome or provide an antidote to this toxicity.

The problem is especially unsettled with regard to *G. polyedra*, the major red tide organism off southern California, where the question of toxicity is thoroughly confused. We have found no toxicity in some samples, low toxicity in others, and a different (from *catenella*) type of toxicity in others. Our results conflict with reports of other investigators. The entire question of *G. polyedra* toxicity might be settled if we can learn to modify our chemical tests so they are applicable directly to the dinoflagellate. Also, the appearance of a different type of toxicity in some samples of *polyedra* could be quite significant to the monitoring problem. Similar contradictions exist in reports of toxicity in *G. tamarensis*. We think the entire problem could be clarified by knowledge of just how the toxin is "masked" in its native state and what conditions lead to its "unmasking".

Isolation method

We have made progress in the initial stages of our investigation of the toxin in *G. breve*. This progress consists in development of an efficient isolation method and resolution of the toxic principle into two pure components. We are now ready to undertake chemical investigations in anticipation that such knowledge will allow us to develop a chemical assay for these toxins as well.

Our work with the dinoflagellates has been in collaboration with Dr. Francis Haxo, who has grown these various organisms successfully in culture. This assurance of a continuous and reliable supply is a clear requirement for successful completion of the project.

Mass Culture Of Toxic Dinoflagellates

F. T. Haxo

San Diego
R/FA-18b

Dinoflagellates comprise a physiologically diverse group of some thousand or more species of microalgae and are important primary producers in the marine food chain. Production of toxic metabolites by certain species, with resultant mortalities of marine organisms and public health problems, *e.g.* paralytic shellfish poisoning, has been well documented. Only saxitoxin, produced by *Gonyaulax catenella* and accumulated by shellfish, has been structurally elucidated. The identity of other dinoflagellate toxins remains to be established, and the reality of toxin production by some suspect dinoflagellates, particularly *Gonyaulax polyedra*, has been an open question. In order to contribute to the proper management and development of fisheries resources, it is important to gain a better understanding of which dinoflagellate species are toxin producers and under what conditions, to establish the chemical nature of the toxic products and to develop specific chemical assays for their rapid identification. These are the main objectives of this program which has been undertaken collaboratively

Table 1.
Summary of Laboratory Cultured Dinoflagellate Harvests.

Species	No. of lots	Amt. harvest liters	Cells/ ml	Wet Wght.	Dry Wght.	Toxicity
Gonyaulax polyedra	7	250.5	1.93×10^4	141.5	20.20	-
Gonyaulax catenella	3	44.0	1.58×10^4	9.0	0.95	+
Gonyaulax tamarensis (Plymouth)	2	40.0	1.02×10^4	13.8	1.70	-
Gonyaulax tamarensis (New England)	1	14.5	4.32×10^3	2.8	0.22	+
Amphidinium carterae	1	17.0	1.47×10^6	10.8	2.52	not yet determined
Gymnodinium breve	13	1260.0	2.87×10^4	145.1	27.37	+

with Professor H. Rapoport, Department of Chemistry, University of California, Berkeley.

Mass culture effort succeeds

The mass culture effort, essential to furthering the objectives of this program has been very successful during the past year. Improvement of existing facilities has essentially tripled our controlled culture space and increased our capability for simultaneous culture of dinoflagellates having different light and temperature requirements for optimum growth. Culture procedures have for the most part been adapted from our earlier work or from standard methods developed by others. The various species are grown as unialgal cultures under constant illumination in enriched seawater medium (*Gonyaulax* and *Amphidinium* species) or in synthetic seawater (*Gymnodinium breve*) in 2.8-liter stationary flasks, eight to ten liter bottles or in 200-liter polyethylene drums. Cells are harvested by continuous-flow centrifugation. Quantification of harvests is accomplished by measurement of cell number, wet weight and dry weight after freeze-drying. The lyophilized powder is sent to Professor Rapoport for toxicity determination and toxin studies.

Examining stock cultures

After preliminary examination of stock cultures maintained in our laboratory, a concerted effort was launched to obtain various strains and species suspected of being toxin producers. Accordingly, during the Spring and Summer of 1974 numerous local water samples were collected and individual cells of desired species were isolated and brought into culture. Eight isolates were thus obtained - *Prorocentrum micans, P. gracile, Gymnodinium splendens, Fragellidium heterolobum, Gonyaulax polyedra* (two strains), *G. catenella* (two strains). In addition to these local isolates, eight other stocks from various laboratories have been added to the test collection - *Gonyaulax polyedra* (three strains), *G. tamarensis* (three strains), *G. excavata* and *G. acatenella*.

Gonyaulax polyedra, the principal red-tide producing dinoflagellate of Southern California waters, received major attention during this year's culture efforts because of its reported mild toxicity and suggested use as a food source. Five clones isolated from three geographical locations have been grown and tested for toxicity and saxitoxin content and two additional strains have been brought into culture but not yet tested. A number of field collections of mixed red-tides composed of 80-95% *G. polyedra* have also been made available for analysis.

In-field system

The development of an in-field harvesting system utilizing a portable generator, immersion pump and continuous centrifuge have greatly facilitated the collection of natural blooms from inshore waters. Tests on this species have so far failed to reveal the presence of saxitoxin. Thus, results to date suggest that public health problems possibly associated with *G. polyedra* blooms are not related to the production of saxitoxin by this species. Additional strains and cells grown under different conditions as well as red-tide harvest will be tested in future weeks. A modest program of shellfish collection in San Diego County made in coordination with those of the California State Department of Public Health has been started: a few collections are available for specific saxitoxin analysis.

Complex toxicity

The complexity of toxicity and natural populations of dinoflagellates was indicated by the appearance in Southern California waters of the chain-forming *Gonyaulax catenella*, the well known saxitoxin producer and source for shellfish poisoning. This alga, usually associated with more northern and colder waters in the northeastern Pacific, occurred in small numbers off La Jolla in March, 1974. Whether its presence here represents a rare southerly intrusion or whether a distinct strain adapted to warmer waters is involved, is a subject for further study. Two isolates have been mass cultured and show a high toxicity and the presence of saxitoxin. This material is being used by Professor Rapoport to further develop the chemical assay tests previously limited to purified saxitoxin and shellfish.

Application of the assay to suspect strains of *Gonyaulax tamarensis* has yielded preliminary data which show that the type species from British waters is negative both by bioassay and saxitoxin test. On the other hand a 1972 isolate of the same species from the New England coast tests strongly positive. Arrangements have been made for shellfish collected during the recent New England red-tides to be shipped for specific saxitoxin testing.

Fastidious *Gymnodinium*

The more fastidious *Gymnodinium breve* (Wilson strain) from the Gulf of Mexico has been under continuous mass culture and as estimated, raw material grown here during the past year has yielded 20-25 mg of partially purified brevitoxin, an amount sufficient to advance the structural studies being conducted at Berkeley. In one harvest 80% of the toxin produced was found to occur intracellularly as contrasted to that released into the surrounding medium; hence only the collected cells are being used for toxin isolation at this time. The results of all laboratory cultured material are summarized in Table 1.

In ancillary studies on the photosynthetic pigment composition of dinoflagellates, we have encountered a unique situation in *G. breve*, the Florida red tide organism. It apparently lacks peridinin the ubiquitous and major carotenoid of dinoflagellates (or its rarely encountered replacement Fucoxanthin). Since peridinin functions as a blue-green light absorbing pigment for photosynthesis, its absence may have interesting photophysiological, ecological and taxonomic implications in studies of this toxin-producing phytoplankter.

Economics of Marine Resources Decision Modeling

San Diego
R/ME-2

James J. Sullivan

A student anthropologist signs on as a hand for two sea voyages to immerse himself in the community of fishermen. A young economist embarks on a theoretical analysis of the fisheries management and the reward structure for fishermen.

The objective of this project is to afford selected advanced graduate students in the social sciences research experience in dealing with marine resources problems that are addressed to develop information and alternatives for marine resource policy making. Each year interns will be competitively chosen to receive support to work on the dissertation topics that address important issues in marine resource policy making.

The students' dissertation research will be focused on the "social science" issues inherent in marine resource management. Their contributions should provide a broader perspective to policy makers and simultaneously broaden their own perspective as well as those of the scientist they are affiliated with.

Agency affiliation

The students will spend one-half of their time at an appropriate agency and be affiliated with the appropriate agency scientific research group.

There are basically two related studies involved. Tracy R. Lewis is studying the economics of the tuna industry. Michael K. Orbach is studying the socio-economics of the community structure of the users of the tuna fishery. More specifically, the work of Lewis and Orbach in cooperation with the NMFS (National Marine Fisheries Service) population dynamics group is reported on below:

Research at sea

Orbach began the grant year by continuing to lay the groundwork for field observations—collecting economic histories, statistics and references and generally making himself known around the tuna industry.

He signed on a 500-net ton seiner with a Portuguese crew for the first trip of the 1974 season and began to prepare himself and the crew for his participant observer/fisherman status.

This first experience at sea gave him an opportunity to observe first-hand the interaction of the crew, to follow radio transmissions between boats at sea and from boats and crews to their home bases and families. This helped him gain an understanding of the processes by which the resource is found and allocated within the fleet.

He also observed disputes between boats at sea over rights to the resource and collected data on the perceptions and effects of risk and uncertainty among the crew.

After his return, he drafted preliminary papers on two portions of the research, the inter-fleet communications systems and the onboard processes of learning, sanctioning and confrontation. The outline derived

formed the basis for future work on the project.

Travel to Wales

Orbach substantiated his findings through research at Memorial University, St. John's, Newfoundland and Cardiff, South Wales, where he also attended the Conference on Socialization to Maritime Occupations at the University of Wales Institute of Science and Technology.

Before leaving on a second working sea voyage in late 1974, he drafted portions of his thesis concerning resource rights and the effects of risk and uncertainty on the behavior of both owners of the industry and the fishermen themselves and continued to collect data on the fishing community and industry in general.

His second trip was aboard a 1,100-net ton seiner with an Italian, Mexican and "down-south" crew. Orbach will present a paper at the 1975 meetings of the Society for Applied Anthropology in Amsterdam.

Share system

Lewis worked with staff members at the National Marine Fisheries Service and with the Economics Department at UC San Diego, to study two aspects of marine resources: an empirical and theoretical analysis of optimal resources management in ocean fisheries, and a theoretical study of the "share payment system" peculiar to ocean fishermen.

For the first study, socially optimal programs for allocating resources are derived in a theoretical and empirical study of the Eastern Pacific Yellowfin Tuna Fishery. The fishery is managed by choosing the rate of catch in each time period to maximize the discounted net economic returns from the fishery over time. The effect on resource allocation for random variations in the availability of the stock, which are caused by fluctuations in the environment, and uncertainty regarding the future demand for the resource are examined using computer simulation techniques.

Empirical relationships

During this year, the biological and economic characteristics of the fishery have been analyzed, and all the empirical relationships needed to complete the study have been estimated. Computer simulation techniques for evaluating possible resource allocation programs have been developed and tested. Using these techniques, optimal programs have been derived under deterministic conditions—where all biological and economic processes in the fishery are completely predictable.

The analysis of optimal programs when there are fluctuations in the availability of the stock and uncertainty regarding the future demand for the resource is partially completed. Preliminary results indicate that the optimal rate of consuming the fishery resource depends on social attitudes towards risk in the returns from the fishery; the usual practice of using the discount rate to capture social risk attitudes is generally not appropriate in dynamic stochastic models of resource allocation; and the optimal rate of current resource consumption decreases when the future availability and future demand for the resource become more difficult to predict.

Uncertain yield

The second study is a theoretical investigation of the "share system of payment" that occurs in the fishing industry. Commercial fishermen are usually paid a certain share of the "take" from each trip at sea rather than the usual wage that most workers in other industries receive. It is well known that the economic yield from fishing is quite uncertain because of random fluctuations in the environment and the unpredictability and variation in economic conditions affecting the fishery. It is concluded in this study that the system is an efficient device for fishermen and boat owners to share the risks from production, and that both parties naturally prefer the share method of payment to the other more conventional wage system used in other industries.

Evaluation of Alternative Management Systems for the Eastern Tropical Pacific Tuna Fishery

San Diego
State University
R/ME-3

V. G. Flagg

Interviews with boat captains, fishermen and others involved in the Eastern Tropical Pacific tuna fishery indicate that some form of restriction on licensing of vessels may be needed to ensure the maximum sustainable yield at the least possible social cost.

Substantial profits in the eastern tropical Pacific tuna fishery have led to significant numbers of new vessels entering the fishery. Many people concerned with the industry suggest that some form of restriction upon entry is necessary in order to help society reap the greatest possible sustained harvest of fish at the least possible social cost. This project, which began in April 1974, is engaged in investigating and evaluating various alternative management programs in order to determine the potential economic impact of each possible program upon the producers of tuna, the consumers of tuna, and society at large.

Optimal number

Since most proposed management systems limit in some way the number of vessels engaged in a fishery, it must be determined what optimal number of vessels a given fishery can utilize efficiently. The yellowfin tuna fishery can be divided into baitboats, small purse seiners, and large purse seiners. As a preliminary part of this project, an intensive study of cost functions of baitboats was conducted through interviews with boat skippers, fishermen, and others in the industry. A study of costs of purse seiners will be undertaken next, and when it has been completed, it will be possible to evaluate the role each component of the fishery should play in the efficient harvesting of the resource. A study of costs is also necessary to predict the economic effect upon different categories of fishing vessels of the imposition of some limitation device, such as licenses, landings fees, or fisherman's quotas.

Feasibility of a Black Cod Trap Fishery in Monterey Bay

Moss Landing
Marine Laboratories
R/FA-21

Gregor M. Cailliet

Estimating the quantity of black cod that can be taken on a sustained yield basis, estimating the ecological role of the black cod in deep waters of Monterey Bay and indicating the most practical techniques, places and times for capturing the species will provide information and advice concerning the utilization and conservation of this resource in central California.

As a result of our preliminary work three fishermen from Moss Landing and seven from Monterey are presently fishing for black cod (sablefish) with traps in Monterey Bay, thus emphatically establishing the feasibility of such a fishery on a short-term basis. The total pounds landed commercially for the months of January through July, 1974, were two-and-a-half times the landings during the same months in 1972. Most of the increase was due to continued fishing during the salmon and albacore seasons since in 1972 the sablefish longline fishermen generally switched to salmon and albacore.

Setting traps

Research accomplished during the grant year included 52 day-cruises to set and retrieve sablefish traps over a 13 month period, with traps set at 50 (34 traps set), 100 (44), 300 (77), 500 (37) and deeper than 600 fathoms (11), resulting in a total of 203 trap sets. A total of 2632 sablefish were caught; 1182 of them were saved for examination of sex, age, reproductive stage, and stomach content analysis. The remaining 1450 fish were measured, tagged and returned to the sea. To date we have recovered 42 fish (2.9%), 37 from commercial fishermen and five during our operations, all from Monterey Bay. We believe that the returned tags represent an underestimate since the fishermen admit that they return less than half the tags they find, and since tag returns continue to come in. Eight hundred fifty-nine

additional fish were analyzed from seven visits aboard commercial fishing boats, and 192 sablefish were captured by trawls, seines and hook and line by Moss Landing Marine Laboratories personnel. Thus the total number of sablefish analyzed during the grant year was 3683.

Determining age

Preliminary age determinations on scales and otoliths suggest that sablefish in Monterey Bay reach at least 12 years of age. Age class analysis is presently under way. Gonad indices show that the majority of sablefish spawn in deep water (somewhere deeper than 300 fathoms) during the winter months. Our trap-caught fish showed a sex ratio favoring females by four to one while the trawl-caught sablefish had about equal numbers of males and females.

Adult sablefish are top carnivores and feed primarily on hake, octopus, flatfish, squid, shrimp and various other bottom fishes, while younger sablefish are more pelagic and feed on small squid, anchovies and euphausids. Feeding habits are still being investigated.

Longliners switch

It was not possible to compare the longline catch rates with those of traps since all local longliners switched to traps during the early weeks of our project. However, James E. Hardwick, Associate Marine Biologist with the Monterey office of the California Department of Fish and Game, is presently working up the longline data for the several years prior to our project. He will work with us to analyze in detail the more practical and economic aspects of the Monterey Bay sablefish fishery, past and present.

Comparing catch

Catch rates were compared for three different baits. Squid caught significantly more fish per trap (17.8) than anchovy (8.4) or herring (7.5). Soak times also affected catch rates with four-hour sets catching the most fish per hour but one- to two-day sets catching the most fish per trap. At 300 to 500 fathoms catches ranged from approximately twenty-five to 300 pounds per trap, and the traps were amazingly selective at these depths. Only eleven other species of fish were caught in small numbers at the 50-fathom station, while nine other species wee caught in traps set deeper than 300 fathoms. In every trap set between 100 and 500 fathoms sablefish never contributed less than 95% of the poundage caught.

Trap-caught sablefish ranged in size from 33 to 94 cm Standard Length and in weight from one to 23 pounds (0.5-10.5 kg). All size classes reported for sablefish in the literature were found in Monterey Bay. Young sablefish (19-36 cm S.L.) were caught only in commercial purse seines, shallow otter trawls and by hook and line. The commercial bottom trawlers in Monterey Bay drag between 40 and 90 fathoms and generally catch small fish (40-60 cm S.L.). The mean size of trap-caught sablefish increased with depth and the largest fish were caught deeper than 600 fathoms. The maximum depth at which sablefish were caught was 1000 fathoms (significantly deeper than the previously recorded maximum depth), and in these traps the grenadier *Coryphaenoides acrolepis* and the codling *Antimora microlepis* were as abundant as sablefish. Changes in size frequencies by month and depth are presently being analyzed.

Since the grant was extended at no cost to Sea Grant for three months, final completion of the entire project will occur at a later date. Early results will be presented at the January, 1975, meetings of the Cal-Neva Chapter of the American Fisheries Society and will be published in the transactions of those meetings.

MARINE PRODUCTS

This less familiar area of inquiry nonetheless touches the lives of ordinary citizens more than the titles of its projects might suggest. Consumer acceptance of canned marine products might be improved if researchers can perfect techniques under examination to impede or prevent unpleasant color changes or odors in fish between catch and canning. Another side of the research picture in this category emphasizes taking advantage of rather than averting natural processes - utilizing environmentally acceptable natural substances to prevent marine fouling, for instance, or encouraging the bacteria that might ferment fishery wastes and residues into edible substances strange to some tastes but nutritious and possibly even good-tasting; or isolating medically useful natural substances from Pacific Coast algae.

Dr. L. H. DiSalvo carries reef subsamples (coral heads) to respirometer dome (right) to measure oxygen consumption rates.

Antioxidants for Marine Lipids

Davis
R/MP-1

H. C. Olcott

There is a continuing search for acceptable antioxidants to control oxidative rancidity of marine food products, all of which contain highly unsaturated fatty acids susceptible to attack by oxygen

In the 1972-73 report we outlined the rationale for a continued study of antioxidants, the use of which would increase the stability of fish products. Our experiments led to the identification, isolation, and characterization of a new type amino acid derivative, namely the free radical, proline nitroxide. A paper describing these observations was recently published. The possibility of the practical utilization of proline nitroxide is limited by its solubility characteristics. We therefore have continued to search for antioxidants with more promising properties.

Stable free radicals

Some years ago we showed that some stable free radicals were very effective fish oil antioxidants. This work suggested to us that ethoxyquin, an effective and accepted antioxidant for field crops might well be oxidized to a stable free radical in a system containing unstable lipids. Recent work has indicated the merit of this concept. Ethoxyquin nitroxide has been isolated, purified, and characterized. This free radical is not only stable but also a more effective antioxidant than the original ethoxyquin when assayed in the unsaturated hydrocarbon, squalene.

During the course of these studies, Patricia Murphy, a graduate student, discovered that an organic compound widely used as a buffer, could yield a free radical by simple oxidative procedures. This observation is being published.

Abstracts of three publications follow:

Lin, James S., Vega Smith and Harold S. Olcott. *Loss of Free-Radical Signal during Induction Period of Unsaturated Lipids Containing Nitroxide Antioxidants*. J. Agr. Food Chem., Vol. 22, No. 4, 1974.

Stable free-radical nitroxides have marked antioxidant activity in unsaturated lipids. The amount of residual nitroxide can be estimated from the electron paramagnetic resonance (epr) signal. With three different nitroxides in squalene at 37° the signal gradually decreased during the induction period. Only when it was no longer or barely detectable, did active uptake of oxygen begin. At 50° with squalene and with menhaden oil, active oxidation began while the nitroxide signal was still measureable. In squalene at 37°, the three nitroxides studied, Tempol (2,2,6,6-tetramethyl-4-piperidinol-*N*-oxyl), Synvar 611 (4',4'-dimethylspiro[5a-cholestane-3,2'-oxazolidin]-3'-yloxyl), and Synvar 614 (2-[10-carboxydecyl]-2-hexyl-4, 4-dimethyl-3-oxazolidinyloxyl), had relative antioxidant activities at equivalent molarities of approximately 2:1.2:1. A simplified method for following weight gain and epr signal without transfer of sample is described.

Lin, James S., Theresa C. Tom, Harold S. Olcott. *Proline Nitroxide*. Agricultural and Food Chemistry, Vol. 22, No. 3, Page 526, May/June 1974.

Proline nitroxide, a relatively stable free radical, was synthesized by the oxidation of *N*-hydroxyproline. Some chemical and physical characteristics are described. Proline nitroxide, like some other stable free radicals (Weil *et al.*, 1968), has antioxidant activity in unsaturated lipids.

Murphy, Patricia A., James S. Lin, and Harold S. Olcott. *Peroxide Oxidation of Tris to a Free Radical*. Archives of Biochemistry and Biophysics 164, 776-777 (1974).

Summary. Tris is oxidized to a free radical by peroxide-tungstate, more readily at alkaline pH than at neutrality.

Studies of Fish Muscle Proteins

Davis
R/MP-2

W. D. Brown

The development of severe brown discolorations in precooked tuna frozen and stored or shipped before canning prevents significant modification of existing technology in the processing of this seafood. If the problem were alleviated, fish could be precooked near point of capture, and the flesh removed, frozen and subsequently transshipped to the cannery.

We have continued our studies in this area in the hope of finding means of preventing surface discoloration of frozen precooked skipjack tuna loins. The presence of these rather severe brown discolorations prevents significant modification of existing technology. Should the problem be alleviated, fish could be precooked near point of capture, the loins removed and frozen, and subsequently be transshipped to the U.S. for

canning. Our work to date has established that two types of reactions are probably involved. The first is the so-called Maillard or nonenzymatic browning reaction, which apparently results from reaction of the sugar ribose (released from tissue complexes during frozen storage) with protein or free amino acids. The second involves lipid oxidation and resulting production of brown colored products. We have developed (by modification of existing procedures) a method for the specific measurement of free ribose in fish muscle, and have used known methods to evaluate the extent of lipid oxidation. A number of trials have been made using various dips and glazes on the surface of precooked loins prior to freezing; loins so treated have been stored for several weeks, then thawed and the extent of discoloration noted. Most treatments to date have been ineffective. Materials evaluated to date include a variety of antioxidants and chelating agents.

Treatments effective

Two treatments have proven effective. When it became apparent that lipid oxidation was a contributory factor to the discoloration, a number of experiments were done to evaluate the effect of removal of subcutaneous lipid. Such lipid layers in skipjack tuna may be removed fairly readily by physical means. Raw fish were skinned and the lipid layer removed on one side of each fish, the other side being left as a control. Variations in such treatment included washing skinned surfaces with dilute detergent, applying antioxidant to the skinned surface and injecting antioxidant materials subcutaneously in the sides of fish not skinned. After standard processing and three weeks of frozen storage the skinned loins (without antioxidant) showed significant improvement in surface color relative to the control sides.

The second treatment that proved effective was attempted following a suggestion from industry personnel that the proposed treatment might yield positive results. In this study, halves of individual skipjack tuna were frozen in a water glaze while the other halves were frozen packed in lard (commercial brand, containing added antioxidants). Following three weeks of storage, samples were removed, steamed, and discoloration evaluated. The loins packed in lard showed no objectional browning, while the control halves were browned significantly. Further work in these areas is in progress. We are tentatively assumming that the lard is acting as an effective oxygen barrier. Oxygen is certainly involved in the lipid oxidation and may be in the browning reaction. We also plan to vacuum pack frozen precooked loins in oxygen impermeable films and evaluate the effectiveness of this treatment.

Lightening surface

In related other work dealing with surface color of fishery products we have begun preliminary experiments (with the cooperation of Dr. Price of the Extension Service) to evaluate treatments designed to lighten the surface color of fresh and frozen fish fillets. This follows the approach suggested by Oregon State researchers. Efforts to date are too limited to permit evaluation of progress. Additional work will be done.

We have continued our work to determine in detail the so-called primary structure of yellowfin tuna myoglobin, i.e. the sequence of amino acids constituing this protein. Such knowledge is not available for any fish myoglobin pigment, although it is available for a number of mammalian myoglobins. The information is useful in helping to understand reactions relative to the pigment properties of myoglobins.

Student thesis

The existence of this Sea Grant project has attracted students to work in closely related areas even though they are not supported as trainees. One such student, John Williams, completed his M.S. degree dealing with the characterization of myoglobins from Atlantic and Pacific green sea turtles. His work included isolation and purification of the pigment from the two species and determination of a variety of chemical and physical parameters to describe properties of these myoglobins. More recently another student has similarly become associated with the project and this past summer he initiated a study of factors involved in the enzymatic reduction of myoglobin in a number of species of fish. Such reduction is important in preventing or reducing undesirable darkening of surface colors and is related to our efforts to "lighten" the color of fish fillets, as briefly mentioned above. He will be continuing this work which will be used for his M.S. thesis.

Desirable color

As indicated in last year's report a number of pet foods that utilize fish products achieve a desirable color through the incorporation of nitrite. The use of this material may be stopped by the Food and Drug Administra-

tion, in which case a substitute would be useful to give these products the desired reddish color. We continue work in this area; however we have temporarily stopped efforts to improve those materials previously suggested for use while we are evaluating the newer approaches to treatment of frozen tuna loins mentioned earlier.

Efforts in this direction have not been initiated; however it is appropriate to mention here that there is now being installed in our pilot plant a new Freon freezer that shows considerable promise. In fact, tuna industry personnel will be visiting to do preliminary freezing trials with tuna loins during the fall of 1974.

Professional Placement

T. Chan, Chemist; doing nutrient analyses, Schoericke and Runyon, Hayward, Calif.

Y. M. Lee, Post Doctorate, Dept. Biological Chemistry, U.C. Davis.

J. Williams, Jr., Extension Seafood Technologist, University of Alaska, Kodiak.

Natural Fermentation Of Marine Products

Davis
R/MP-3

E. V. Crisan and
M. W. Miller

Underutilized marine resources or fishery waste products can be fermented to produce highly nutritional food products. If specific microorganisms can be identified, selected and combined to produce desired fermentative effects, fishery by-products will become not only valuable but palatable as well.

A variety of food products are produced by utilizing the fermentative capabilities of specific microorganisms. During fermentation, these microorganisms modify basic components in the raw food product to produce a fermented food which may be more nutritious, digestible, and/or palatable. Fermentation provides a means of expanding the use of marine resources. The goal of this project is to identify the microorganisms associated with fermented seafoods and determine their role in the fermentation process. These fermentative activities will be utilized to develop new or improved methods for exploiting underutilized marine resources and reutilizing fishery waste products.

Fermented seafoods

Fourteen fermented seafoods were analyzed to isolate and identify their microbial populations. These fermented products included whole animals, e.g. clams, oysters, shrimp, squid, and fish; specific organs, e.g. muscle tissue, gonads, intestines, and roe; and derived products, e.g. fish sauces and pastes. Only seven genera of bacteria were isolated from these products. The sporeforming genus *Bacillus* was common to all products and was represented by eleven different species and numerous sub-strains. A single species of *Pediococcus* was found in six products while five products contained one or more of four species of *Micrococcus*. Single species of *Achromobacter*, *Clostridium*, *Pseudomonas*, and *Serratia* were isolated from individual products. The occurrence of *Bacillus* species in all of the fermented seafoods suggests that they may play a critical role in achieving the desired characteristics in the fermented product.

Major components

Protein and lipid are the major components of marine products which have actual or potential food value. Fishery wastes contain large amounts of unrecovered protein and lipid which represent a significant loss to the world food resource and, in fact, create serious problems of environmental pollution. In addition to these major food components, waste from crab, shrimp, and lobster fisheries contain large amounts of chitin, a nitrogen-containing compound of limited nutritional value. Enzymatic assay procedures developed earlier in this project were used to test the microorganisms isolated from seafoods and other products to ascertain their ability to digest lipids and proteins of marine origin (Table 1). Of the 228 bacterial strains tested, 10.5% of the isolates could digest marine lipids, 69.3% were proteolytic, and 9.6% were chitinolytic. Of the 67 isolates of molds and yeasts, 35.8% were lipolytic and 25.4% were proteolytic; tests for chitinolytic ability are now in progress.

Table 1.
Enzymatic Activities of Microbial Isolates Against Lipid, Protein, and Chitin of Marine Origin.

	Bacteria (228 Isolates)		Molds & Yeasts (67 Isolates)	
	number	percent	number	percent
Lipolytic only	11	4.8%	12	17.9%
Proteolytic only	133	58.3	5	7.5
Chitinolytic only	5	2.2	*	
Lipolytic + proteolytic	9	3.9	12	17.9
Lipolytic + chitinolytic	1	0.5	*	
Proteolytic + chitinolytic	13	5.7	*	
All three activities	3	1.3	*	
No activity	53	23.2	38	56.7

*tests for chitinolytic activity in progress.

Nutritional products

It is expected that underutilized marine resources or fishery waste products can be fermented to produce highly nutritional food products. On the basis of data now available, it will be possible to select microorganisms exhibiting one or a combination of specific enzymatic activities which can be used to ferment a given marine product. Studies are being conducted to evaluate the parameters involved in selective fermentation wherein an undesirable or less valuable component can be reduced or modified without affecting the existing nutritional value of the substrate. This information will be used to develop processes designed for converting specific fishery waste products and underutilized resources into acceptable food products of increased nutritional value.

Theses Completed

Young, Raymond Tom, 1973; M.S. Thesis, "Assay for lipolytic and proteolytic microorganisms using marine lipid and protein sources.

Marine Natural Products Chemistry

San Diego
R/MP-4

David John Faulkner

Studies of antibiotic activity in marine bacteria may lead to the discovery of an organic marine coating that impedes fouling without the introduction of heavy metal or chlorinated organic toxins present in antifouling paints produced and used today.

During the year 1973-74 we began a program to isolate marine bacteria. The purpose of this program is twofold. It had been observed that marine bacteria are the first organisms to foul a clean surface placed in seawater. We therefore felt that incorporation of an antibacterial agent into marine coatings might slow the process of fouling. An additional reason for the isolation of marine bacteria is that some species produce antibacterial compounds, presumably as part of a chemical defense system.

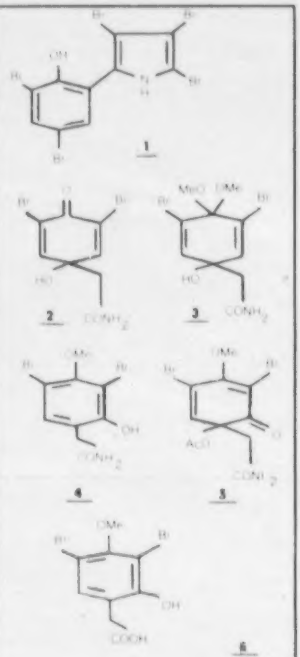
We have isolated over 25 pure cultures of marine bacteria from seawater samples. Since we have not identified many of these cultures, it is probable that there may be some duplication within our collection. We have also obtained pure cultures of marine bacteria and fungi which are pathogenic to crustaceans.

Antibiotic activity

The marine bacteria were tested for antibiotic activity by standard techniques. To date, every culture which shows antibiotic activity is also coloured. There is not, however, a direct correlation between pigmentation and antibiotic activity since other coloured bacteria show no antibiotic activity. We have shown that at least one of the antibiotic-producing marine bacteria is autotoxic.

As can be seen from the Table, compounds which are active against marine bacteria are not necessarily active against "terrestrial" bacteria, such as *S. aureus*. In particular, attempts to eliminate marine bacteria with penicillin or streptomycin seem destined to failure, despite their popular use in culture media. We have found several

	Marine Bacteria				Human Pathogens			
	102-3	96	*Chromobacter*	*V. anguillarum*	*S. aureus*	*E. coli*	*B. subtilis*	*C. albicans*
***Chromobacter sp.* Metabolites**								
p-hydroxybenzaldehyde	+	+	+	NT	+	-	-	+
n-propyl-p-hydroxybenzoate	NT	+	-	NT	-	-	-	-
tetrabromopyrrole	NT	+ +	+	NT	+ +	+	NT	+
hexabromo-2-2'-bipyrrole	NT	+	+	NT	-	-	NT	-
1	NT	+ +	+	NT	+ +	NT	NT	NT
102-3 Investigation								
3-bromoindole-2-carboxylic acid	-	-	+	-	-	-	-	-
3-bromoindole-2-carboxaldehyde	NT	-	NT	-	+	-	+ +	+ +
2-bromoindole-3-carboxaldehyde	-	-	-	-	-	-	-	-
5-bromoindole-3-carboxaldehyde	-	-	-	-	+	-	-	-
Algal Metabolites								
Laurinterol	-	-	-	-	+ +	-	+ +	-
Johnstonol	-	-	-	-	-	-	-	-
Pacifenol	-	-	-	-	-	-	-	-
Prepacifenol epoxide	-	-	-	-	-	-	-	-
Isojohnstonol	-	-	-	-	-	-	-	-
Violacene-1	-	-	-	-	d +	-	-	-
Violacene-2	-	-	-	-	-	-	-	-
Violacene-3	-	-	-	-	-	-	-	-
Bromophenols								
4-bromo-3-methylphenol	+	+	+	-	-	-	-	-
3, 5-dibromo-o-cresol	+	-	+	+	-	-	-	-
Sponge: synthetic intermediates								
2	NT	+ +	NT	NT	+ +	NT	NT	+ +
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	+	+	+	+	+ +	-	+	-
6	-	-	-	-	-	-	-	-



compounds which are active against marine bacteria. It is significant that these compounds were obtained from sponges or marine bacteria.

Screening extracts

Our research on antibiotics from marine algae has produced an interesting result which may serve to illustrate the pitfalls which may be encountered when screening crude algal extracts. During our early work on constituents of the digestive gland of *Aplysia californica* (sea hare) we showed that the "non-polar fraction" was strongly antibiotic against *S. aureus*. We were able to show that the "non-polar fraction" consisted of halogenated monoterpenes from two species of red algae, *Plocamium cartilagineum* and *P. violaceum*. After an extensive study of the chemistry of the metabolites from these algae, (see report by Jon Mynderse) we found that none of the pure components of the mixtures of metabolites from either *Plocamium* showed more than slight antibiotic activity. We assume that the antibiotic activity is due to an autocatalytic decomposition of the crude extracts which is accompanied by the evolution of hydrochloric and hydrobromic acids. A detailed study of this process is currently underway.

Wide spectrum

In summary, we have shown that many "commercial" antibiotics are not effective against marine bacteria; we have found several compounds with a wide spectrum of activity against marine bacteria; we have elucidated the structure of a number of polyhalogenated monoterpenes from *Plocamium* species.

Natural Compounds From Marine Organisms

Riverside
R/MP-5

J. J. Sims

Little is known about the organic compounds contained in marine organisms. This project is exploring marine algae as a potential source of antibiotics. A variety of natural bromine- and chlorine-containing compounds have been isolated, one of which possesses antibiotic activity at a level ten times that of streptomycin.

The accomplishments of this grant are contained in the following publications:

1. Fenical, W., James J. Sims and P. Radlick
   1973. Chondriol, a Halogenated Acetylene from the Marine Alga *Chondria oppositiclada*. Tetrahedron Letters, 313-316.
2. Hirshfield, D. B., W. Fenical, G. H. Y. Lin, R. M. Wing, P. Radlick, James J. Sims
   1973. Marine Natural Products. VIII. Pachydictyol A an exceptional diterpene alcohol from the brown alga, *Pachydictyon coriaceum* J. Am. Chem. Soc. 95: 4049-4050.
3. Sims, James J., G. H. Y. Lin, R. M. Wing and W. Fenical
   1973. Marine Natural Products IX. Concinndiol, a bromoditerpene alcohol from the red alga *Laurencia concinna*. J. Chem. Soc. Chem. Comm. 470-471.
4. Fenical, W., James J. Sims, D. Squatrito, R. M. Wing and P. Radlick
   1973. Zonarol and isozonarol, fungitoxic hydroquinones from the brown seaweed *Dictyopteris zonarioides*. J. Org. Chem. 38: 2383-2386.
5. Fenical, W., James J. Sims, P. Radlick, R. M. Wing
   1973. Zonarol and isozonarol, fungitoxic hydroquinones from the brown seaweed *Dictyopteris zonarioides*. Food-Drugs from the Sea Proceedings 1972, Marine Technology Society 199-202.
6. Fenical W. and James J. Sims
   1974. Cycloeudesmol, an antibiotic cyclopropane containing sesquiterpene from the marine alga, *Chondria oppositiclada* Dawson. Tetrahedron Letters, 1137-1140.

Compounds isolated

The first natural bromine and chlorine containing compound was isolated from a *Laurencia*.

An algal antibiotic, Laurintorol, was discovered shown to be as active as Streptomycin.

Hydro Lab Coral Reef Conservation Experiment

Berkeley
R/MP-6

Louis DiSalvo

During a saturated diving mission a method of assaying the "health" of a coral reef was developed which suggests a broadly applicable system for determining reef pollution stress.

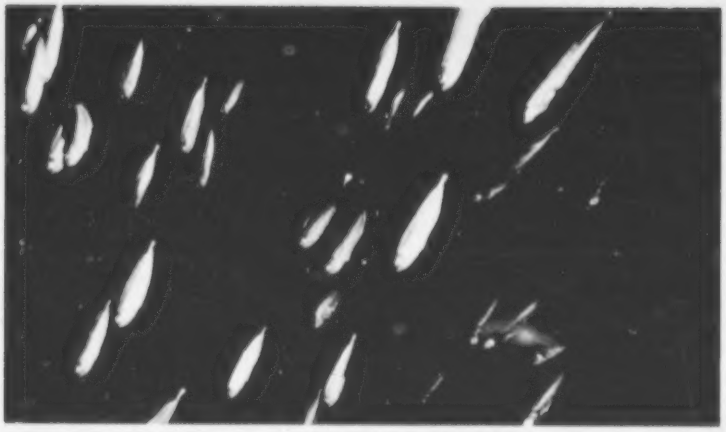
The purpose of the project was to determine methods of *in situ* biological and chemical assays of stress on coral reefs whether these stress effects are due to sewage, oil pollution, heavy metal pollution, or other stress including natural catastrophe.

Baseline information

Information obtained in the oxygen metabolism research can be used as baseline information concerning the normal metabolic rates of reef substrates due to bacteriologic activity. Data obtained on a new type of *in situ* bioassay of micro-grazing of the internal reef surfaces may serve as a systems indicator of pollutant stress to the reef internal system. Significant changes in these rates may be interpreted as stress (pollutant) effects on the reef internal regenerative system.

Measurements were obtained during the 7-day saturated diving mission which indicated a similarity of reef substrate oxygen consumption measurements on a universal scale, suggesting this method of assay of the "health" of the reef may provide a broadly applicable method of assaying for reef pollution stress. Micro-grazing background determination measurements were carried out, providing scientifically interesting assays of this phenomenon. Although measurements of this phenomenon were not obtained with the system under stress, it shows promise of being a valid *in situ* environmental bioassay.

72



Jack mackerel off Santa Cruz Island photographed by the "drop camera."

OCEAN ENGINEERING

Man has long been in awe of great and often unquantified forces of the sea. When it has been necessary to protect himself from these destructive forces it has almost always been by the elaboration of massive engineering structures to confront nature. An understanding of coastal processes is now providing the basis for design solutions utilizing natural processes rather than opposing them, focusing on the critical problem—control by the rapier rather than by the bludgeon.

As man extends his activities seaward he finds that he needs new facts and an understanding of this unfamiliar regime. How much weight will bottom sediments support, how strong and changeable are the currents, and what are the extremes of wave climate? All are questions to be answered if many of the physical resources of the sea are to be intelligently employed or if we are to trespass in this domain with pipelines and structures.

Wave Climate Modification In Harbors by Dynamic Breakwater

John D. Isaacs

The analytical and scale-model evaluation of a tethered float breakwater was substantially completed and the scaled-up engineering development was initiated.

During this grant year, the analytical and model scale evaluation of the tethered float breakwater were substantially completed and the engineering development at ocean scale was initiated.

A linearized model for the response of a single float to random wave excitation was developed and extended to allow the calculation of the drag work done on the wave. The float response model was verified by comparing predicted to measured statistics for a one-meter float moored in water 10 meters deep off Scripps Pier. The wave energy reduction theory, extended to arrays of floats, was verified by comparing predicted to measured wave attenuation characteristics of model breakwaters in the wave channel. The analytical model is reported by Seymour and Isaacs (1974). An important contribution to the success of this predictive model was the determination of the appropriate values for the added mass and drag coefficients for spheres in oscillatory flows and under conditions of transverse vibrations induced by vortex shedding. These parameters were found to be influenced substantially by both the relative amplitude of the oscillations and by the presence of the transverse vibrations. The experimental program for the determination of these coefficients is reported by Seymour (1974).

Model evaluation

Testing of model breakwaters at larger scale than previously employed was undertaken in the wave channel at the Hydraulics Laboratory. The floating ballast concept, in which the floats pierce the surface and the ballast remains clear of the bottom was also evaluated in this series of experiments. In addition to spherical floats, cylinders and clusters of cylinders were also evaluated. Mooring loads on the free-floating breakwater assemblies were determined. These experiments provided additional verification of the analytical model. A preliminary report on this evaluation was made by Seymour, Sessions and Wallace (1974).

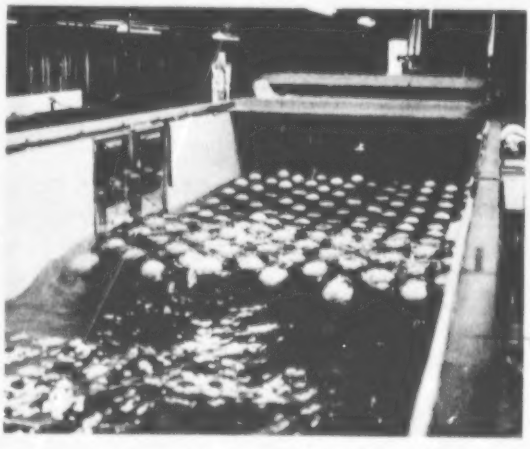
Placement in ocean

A section of a suspended ballast breakwater using 20 cylindrical floats with displacements approximately equal to a one-meter sphere was constructed in cooperation with the U.S. Navy at San Clemente Island in a sheltered location to investigate installation techniques. The floats were fabricated from scrap automobile tires filled with foam. This construction appears to be promising for low cost wave protection in fetch-limited applications.

A site survey was conducted at San Clemente Island to determine the location for the construction of a complete breakwater by the Navy next year. This structure will be approximately twice the scale of the experimental section already installed.

A fully automatic data logging system for evaluation of the wave attenuation effectiveness of the prototype breakwater was procured and is now under evaluation. This system will be used at San Clemente when the large-scale breakwater is installed.

A paper by Seymour and Isaacs (1974) was presented at the Conference on Floating Breakwaters at Newport, Rhode Island in May. This work described the principles and operation of the breakwater and suggested a number of applications including harbor and marina protection, offshore terminals and beach erosion abatement



Tethered float breakwater experiment in laboratory wave channel showing attenuation of simulated ocean waves coming from lower left.

Cooperation with Navy

The Naval Facilities Engineering Command has initiated a development program for the tethered float breakwater which has the goal of producing a transportable breakwater capable of attenuating open-ocean waves. This program will involve ocean testing at progressively increasing scale, material evaluation and system engineering. The subscale work conducted at San Clemente Island described above was in support of this effort. A preliminary film report of the cooperative Navy-Sea Grant work has been prepared. Participation by other government agencies and by industry in this development program is being sought by the Navy.

Wave-Powered Generator

San Diego
R/E-1B

John D. Isaacs

The wave-power program has examined the feasibility of usefully extracting some of the solar energy stored in deep ocean waves, in particular the kinetic energy at the air/sea interface.

The Wave Power Program has examined the feasibility of usefully extracting some of the solar energy stored in deep ocean waves. Of the various ways in which solar energy is manifest in the oceans, this program has dealt with the kinetic energy input resulting from the direct interactions at the air/sea interface, i.e., the wind stresses which drive surace waves. Figure 1 shows some of the estimated dissipation rates of solar power in the oceans.

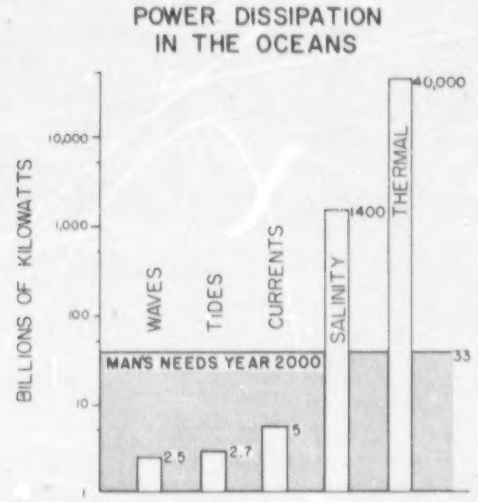


Figure 1. Estimates of power dissipation rates in the oceans.

Energy estimates

The relative magnitudes show that current wave energy estimates are about 3×10^{12} watts. However, this figure is conservative since, unlike tidal energy under most circumstances, wave energy is self-healing. Depending on the fetch and strength of winds, etc., energy extracted can quickly be replenished by the wind.

In examining the various ways by which this source of energy can be tapped, two rather discouraging facts become immediately apparent. Waves, as such, are a very low-grade form of energy, and in their natural state cannot be economically exploited. Also, waves are often aperiodic. One would not expect an eight-foot wave to yield much direct energy (e.g., there are few eight-foot dams in existence). Thus, despite the magnificent display of obvious mechanical power exhibited by waves, any schemes which make use of linkages, pressure chambers, bellow, floats, seasaw arrangements, etc. are economically unattractive. Indeed, history has shown these schemes to have a negligible success rate. For effectiveness the action of the waves must be considerably amplified, and the working device needs to operate in a manner that is substantially independent of the wave period. Stated differently, a device that would attempt to extract energy from the waves should have among its design criteria 1) the ability to amplify the relatively low water head associated with wave height; 2) a broad-band range of response over wave amplitude and frequency; 3) the capacity to respond to smaller waves as well as withstand potentially destructive accelerations from large storm waves.

Vertical riser

Through Sea Grant support, a simple solution to these problems was investigated. The device considered is illustrated in Fig. 2 and consists of a vertical riser containing a flapper valve and a buoyant float at the surface; slack tethered, it responds directly to wave motion. During operation the flapper valve closes for approximately half the wave cycle, forcing the entrained water column to

follow the upward motion of the float. As the float starts to descend on the ocean surface, inertial forces maintain the water on an upwards course, carrying it higher than the wave height.

WAVE POWERED PUMP

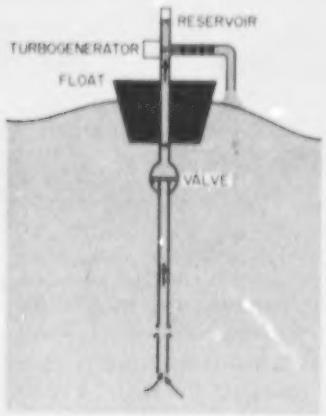


Figure 2

Suitable pressure

Subsequent cycles raise the water successively higher until pressure suitable for power generation is reached. The wave train maintains water flow at the required pressure. The pressure is limited by the length of the pipe and the prevailing sea state. Where winds are consistent and large waves can be regularly anticipated, such as in a trade wind area, significant quantities of energy can be extracted. Figure 3 shows a typical power spectrum of wind waves and swell. On this plot are shown T_h, the natural period of the entire system in motion with the pipe full of water and T_m, the natural period of oscillation of the water within the pipe. As can be seen, T_h and T_m are well without the range of normal wave frequencies. Thus the system is detuned, acts as a band-pass, and hence will respond over a large frequency range.

Working model

After considerable theoretical analysis of the system, a working model was constructed and tested in the waters off the coast of Southern California. The model consisted of an 8" diameter, 200' long free floating vertical pipe, supported at its upper end by a surface-following buoy with a unidirectional flow valve at a point 20' below the ocean surface. A number of test runs were held and the experimental results largely support the predictions of the mathematical model. In 6' significant waves on an 8-second period, the pump produced a mean pressure of 7.5 psi (equivalent to approximately a three-fold magnification of the prevailing waves) in the accumulator tank. Continuous flow at this pressure through a ½" discharge nozzle produced a power output (in the absence of a turbine) equivalent to 60 watts. For the same system parameters and swell conditions the theoretical model predicts a pressure of 7.5 psi showing good agreement with actual results. Optimization of buoy configuration and tank size for the above conditions would have resulted in a power output of approximately 600 watts. Calculations based on the above results show that a 300' long pipe with a 36" diameter will produce an average of 18-20 kw of continuous power in a trade wind area.

Wind waves energy

The study and experimental program indicate that, in principle, it is practical to extract energy out of wind waves. It remains to be shown that the proposed method is economically sound and commercially viable. To do this it will be necessary to test a larger size model over a relatively long period of time. Initial indications are that the results will be promising.

RESPONSE OF WAVE POWERED PUMP TO WAVE SPECTRA

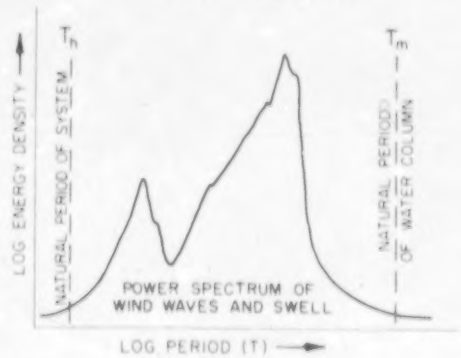

LOG ENERGY DENSITY
NATURAL PERIOD OF SYSTEM T_h
T_m
NATURAL PERIOD OF WATER COLUMN
POWER SPECTRUM OF WIND WAVES AND SWELL
LOG PERIOD (T)

Figure 3. Response of a wave-powered generator to a random sea.

Engineering Properties Of Sea Floor Sediments

San Diego
State University
R/E-3

Iraj Noorany

Studies of the engineering properties of sea-floor sediments yield results of value to foundation engineering work on offshore structures and underwater installations, as well as nearshore developments.

The objective of this project was to determine the engineering properties of sea-floor sediments from the continental shelf off the coast of southern California, and from the deep sea Pacific. Emphasis was placed on determining the effects of sampling on the engineering properties of sea-floor sediments. The design of a 10,000 psi high pressure triaxial test facility for testing sea-floor sediments was finished, but final construction of the test system was not completed by the end of the project. The results of the study are of value for foundation engineering work related to offshore structures and underwater installations, as well as near shore developments.

The test program to determine engineering properties of sediments recovered by SIO's tracked Remote Underwater Manipulator ("RUM") was completed. In addition to these near shore samples, soft brown clay samples obtained from the deep sea in the North Pacific by Kennecott Exploration, Incorporated, were tested for their engineering properties. Although it was intended that some calcareous sediments obtained from the deep-sea drilling project JOIDES be tested, they were not available for this study. The laboratory testing was performed at the Soil Mechanics Laboratory of San Diego State University under the supervision of Iraj Noorany, with the assistance of Elsworth Buchanan, a Sea Grant Trainee.

Evaluating system

Plans for the development of a unique high pressure triaxial test facility for testing sea floor sediments under ambient pressures up to 10,000 psi were developed during 1972-73. The components of this complex facility were constructed and the entire system was evaluated in a series of test runs. Several problem areas were identified and successful modifications made. The system's construction was not fully completed at the end of the project term, however, because two high pressure special load cells had to be returned to the manufacturer in England for repair.

The system is designed to permit testing of sea-floor sediments under high ambient pressures simulating the in-situ hydrostatic pressures. Furthermore, the system is designed so that the process of sampling and lifting of the soil sample out of the water can be simulated under tightly controlled conditions. The system is composed of three main components. The first consists of two 10,000 psi triaxial chambers, equipped with internal load cells for accurate measurement of the load, and differential pore pressure transducers for measurement of pore-water pressures. The second consists of a set of self-compensating mercury pots, enclosed in high pressure cylinders, capable of creating a small net effective stress (the difference between the cell pressure and the back pressure) which would remain constant regardless of the fluctuations in the main pressure source. For example, this system enables us to maintain a cell pressure of 9910 psi and a back pressure of 9,000 psi. The third main component is a hydraulic pressure source for generating and maintaining pressures up to 10,000 psi.

Accurate measurement

This unique system will permit accurate measurement of the effect of sampling on the "behavior" of marine sediments. The process of sampling can be simulated by comparing the properties of pairs of samples placed under identical conditions simulating the in-situ conditions and then subjected to the pressure reduction simulating the sampling process.

Elsworth Buchanan, the Sea Grant Trainee for this project, successfully completed his work and received his Master of Science degree in January, 1974. Four publications resulting from this project were described in the annual report for 1972-73. The results of the work during 1973-74 are being compiled for a paper to be published by I. Noorany, G. L. Luke, O. Kirsten and E. Buchanan.

New Applied Developments

San Diego
R/E-6

John D. Isaacs

CalCOFI utilizes photographs taken by a free-vehicle camera to help identify schools of pelagic fish and estimate their density, tasks formerly requiring the employment of a purse seine vessel.

New Applied Developments is a continuing program of exploratory research that has provided the initial investigations and assessments of new ideas to a degree adequate for their evaluation for immediate usefulness or long-term research commitments.

During the past year Daniel M. Brown has developed a free-vehicle camera used to study pelagic fish schools. This "drop camera" system is lightweight and easily tossed over the side of a ship as it passes over a school of fish. The camera automatically takes pictures every 15 seconds and is ballasted so that it sinks slowly. After a certain depth is reached, it releases the ballast and returns to the surface for recovery. If it sinks to a shallow bottom, a back-up release employing dissolvable candy, ice or salt, triggers the ballast release. The entire system is cheap, easy to operate and results can be obtained very soon after recovery.

Aiding CalCOFI

Our present use of the "drop camera" has been to aid the California Cooperative Oceanic Fisheries Investigations (CalCOFI), in particular the California Department of Fish and Game and the National Marine Fisheries Service of the Southwest Fishery Laboratory, La Jolla, during their acoustic surveys of California and Baja California. They use the photographs to help identify the pelagic fish schools and estimate their density, substituting for the previous employment of a purse seine vessel. Along with acoustic data, the photographs then can be used to estimate biomass. The camera system could be used in many coastal zones of the world for identifying fishery resources.

Several other new applied developments are discussed in the Institute of Marine Biennial Report 1972-74 (IMR Ref. No. 74-15).

Cooperating Organizations
(Cumulative List)

American Agar and Chemical Company of San Diego
Brookhaven National Laboratory
California Coastal Zone Conservation Commission
California Department of Fish and Game
California Department of Navigation and Ocean Development
California Department of Public Health
California State Park System
City of Huntington Beach, Department of Harbors and Beaches
Commercial Diving Center, Wilmington, California
Comprehensive Planning Organization, San Diego
Del Monte
Hueneme Fish and Bait Processors, Port Hueneme, California
Hydrolab
Institute of Behavioral Sciences, University of Colorado
Los Angeles County Lifeguards
Massachusetts Lobster Hatchery, Martha's Vineyard, Mass.
National Marine Fisheries Service, California
National Marine Fisheries Service, Woods Hole, Mass.
Naval Oceanographic Office
San Diego City and County Schools
San Diego County Department of Flood Control
San Diego County Department of Public Health
Scripps Industrial Associates
Star Kist
Universidad de Ciencias Marinas, Ensenada, B.C.
UC-Davis Extension
University of Southern California, Harbor Project
Van Camp

PROGRAM SUMMARY

PROGRAM DEVELOPMENT	FY72	FY73	FY74
PROGRAM MANAGEMENT			
Management and Program Development (Frautschy, Shor)	O	O	O
New Projects (Frautschy, Shor)	N	O	O
Management (Moss Landing-Hurley)	-	-	N
EDUCATION/TRAINING			
Graduate Education in Applied Ocean Science (Anderson)	O	C	-
Sea Grant Trainees (Frautschy, Shor)	O	O	O
Scientific Diving Supervisor Training (Stewart)	C	-	-
Undergraduate Training in Marine Technology (Flittner)	O	O	R
Sea Grant Educational Services (Hurley)	-	-	N
ADVISORY			
Ocean Education for the Public (Wilkie)	O	O	O
Marine Extension Services (Cummings)	N	O	O
Publications and Public Advisory Services (Sullivan)	-	N	O
Ocean Engineering Data Center (Johnson)	-	N	O
More Effective Delivery (Thompson)	-	-	N
Geophysical and Geological Data Center for Information on Petroleum Resources (Chase)	C	-	-
Improvement of Methods of Predicting Sea-Surface Temperatures (Gibson)	C	-	-
Marine Advisory Services Expansion (Flittner)	C	-	-
San Diego Law Review (Bratton)	-	-	N/C
COASTAL ZONE STUDIES			
Environmental Conflict Identification (Twiss)	N	O	R
Physical Criteria for Coastal Planning (Inman/Van Atta)	O	O	O
Biological and Ecological Studies of Normal Populations, Natural Variability and Effects of Environmental Changes in the Nearshore Zone (Newman)	C	-	-
Ecological Studies of the Nearshore Zone (Fager/Dayton)	O	O	C
Ecology of Santa Cruz and San Mateo County Coasts (Doyle)	N	O	O
Natural Seepage in the Santa Barbara Channel: Physiochemical Aspects (Mikolaj)	N	C	-
An Investigation of the Seismicity and Earthquake Hazards of the Santa Barbara Channel Area (Sylvester)	N	C	-
Sea Coast Planning Project (Hetrick, et al.)	N	C	-
Monitoring of Pollution Parameters in San Francisco Bay (Wilde)	-	N	O
Recreation Resources of Los Angeles County Coast (Egstrom)	-	N	O
Trace Metal Analysis of Oily Beach Pollutants in the Santa Barbara Channel (Mikolaj)	N	C	-
Organizational Arrangements for Coastal Management (Lee, Scott)	-	-	N
Development and Assessment of Legally Revissible Methods for Coastal Management (Heyman)	-	-	N
An Experimental Study of the Tomales Bay "Sneaker Wave" (Fischer)	-	-	N/C
Legal Techniques for Marine Resources Management (Bowden)	-	-	N
Design of a Computer-Automated Map (Pepper)	-	-	N/C

PROGRAM DEVELOPMENT	FY72	FY73	FY74
FISHERIES/AQUACULTURE			
Uses of Waste in Aquaculture (Cooper/Holmes)	-	N	C
Rearing of Larval Fishes (Lasker)	O	C	-
Economics of Aquaculture (Johnston)	-	N	O
Aquaculture of the American Lobster (Shleser)	N	O	O
Studies of Vertical Migration of Zooplankton (Enright/Isaacs)	C	-	-
An American Lobster Fishery in California (Ford)	O	C	R
California Spiny Lobster Growth (Dexter)	O	T*	-
Historical Levels, Areas, and Routes of Pesticides in the Plankton and Fish of the California Current (Longhurst/Lasker)	C	-	-
Protective Measures for Lobster Aquaculture (Mathewson)	O	R	O
Evaluation of the California Spiny Lobster Fishery and Related Population Characteristics During a Period of Reduced Fishing Effort (Farris)	C	-	-
Abalone Culture (Leighton/Wilson)	N	C	-
Seaweed Resource Management (Cultivation) (Neushul)	N	O	O
Gelidium Resource Management (Barilotti)	-	N	C
Salt-Tolerant Plants (Epstein)	-	N	O
Fishes of the Santa Barbara Kelp Forest (Ebeling)	O	C	-
The Juvenilizing Factor in Crustacean Eyestalks (Faulkner/O'Connor)	C	-	-
Ecology of Benthic Herbivores in the Sea (Connell/Murdoch)	C	-	-
Ecosystem Studies and Mariculture Potentialities of a Coastal Lagoon (Holmes	C	-	-
Toxins from Marine Dinoflagellates (Rapoport)	-	-	N
Mass Culture of Toxic Dinoflagellates (Haxo)	-	-	N
Economics of Marine Resources Decision Modeling (Sullivan)	N	O	R
Feasibility of a Black Cod Trap Fishery in Monterey Bay (Caillet)	-	-	N
MARINE PRODUCTS			
Food Uses of Marine Lipids (Olcott)	N	O	R
Studies of Fish Muscle Proteins (Brown)	N	O	O
Natural Fermentation of Marine Products (Crisan)	N	O	O
Pharmaceuticals from Marine Organisms (Faulkner)	O	O	R
Natural Compounds From Marine Organisms (Sima)	N	O	O
OCEAN ENGINEERING			
Enhancement of Natural Marine Productivity by Artificial Upwelling (Isaacs/Schmitt)	C	-	-
Wave Power (Isaacs) a) Wave Attenuation Studies b) Wave-Powered Generator	-	N	O
Unmanned Sea Floor Work Systems (Anderson)	O	C	-
Engineering Properties of Sea Floor Sediments (Noorany)	N	O	C
Synthesis of Forces on Marine Structures (Paulling)	N/C	-	-
Underwater Cable Dynamics (Webster)	N	C	-
New Applied Developments (Isaacs)	O	O	O
Acoustic Holographic System for Underwater Search (Wade)	N/C	-	-
Composite Materials for Ocean Construction (Tetelman)	N	C	-

N = New Project
O = Ongoing Project
R = Restructured Project
C = Completed Project
T = Terminated Project
*No Final Report

ACTIVITY BUDGET SUMMARY
1973-74

	NOAA Grant Funds	University Matching Funds
Marine Resources Development		
Aquaculture	256,422	155,064
Living Resources (other)	47,910	46,046
Marine Biomedicinals & Extracts	21,518	16,374
Socio-Economic & Legal Studies		
Marine Economics	31,318	14,790
Ocean Law	9,925	14,467
Socio-Political Studies	13,082	5,828
Marine Technology Research & Development		
Ocean Engineering	104,296	77,604
Resources Recovery & Utilization	79,861	43,226
Marine Environmental Research		
Research & Studies in Direct Support of Coastal Management Decisions	34,496	57,481
Ecosystems Research	20,966	4,504
Applied Oceanography	53,453	38,790
Marine Education & Training		
College Level	---	85,491
Vocational Marine Technician Training	4,915	1,000
Other Education (Sea Grant Trainees)	216,000	---
Advisory Services		
Extension Programs	119,872	67,840
Other Advisory Services	74,920	57,026
Program Management & Development		
Program Administration	123,274	93,207
Program Development	2,872	---
TOTAL	$1,215,100	$758,738

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MATCHING FUND SOURCE

1973-74

Abbott Labs
American Agar Co.
Aquarium Museum Docents
California State University, San Diego
Counties of Marin, Sonoma, Mendocino
County of Los Angeles
Donations - Various Donors
Foundation for Ocean Research
Moss Landing Marine Laboratories
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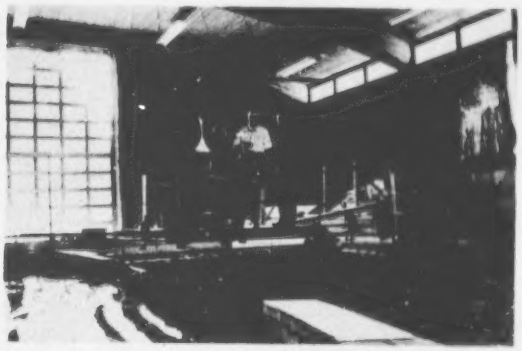
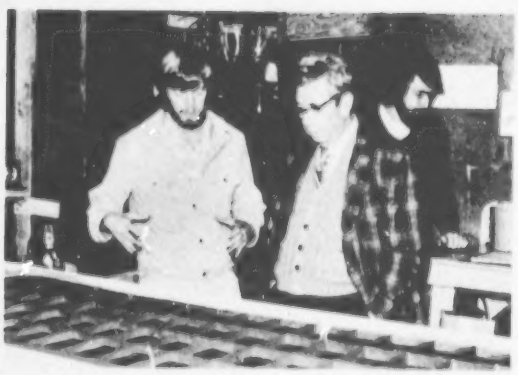
Editor's note: Supplementary material and Trainee reports for individual projects are available at the Sea Grant Publications Office. See address below.



Senator John V. Tunney (left), SIO Director Dr. William Nierenberg (second from left) and (right) IMR Advisory Council Member The Honorable Hugo Fisher of San Diego Superior Court discuss the tethered float breakwater system with one of its developers, IMR Director Professor John D. Isaacs (second from right).



Jon C. Van Olst describes San Diego State University lobster production unit to Harold C. Goodwin, former Deputy Director of the National Sea Grant Program.

Designed and edited by Barbara Ann Firger
Drawings of algae by Christina Good

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